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Volume XI, Number 1 February, 1940

RECORDS

OF

OCEANOGRAPHIC WORKS

IN JAPAN

Compiled by

THE COMMITTEE ON PACIFIC OCEANOGRAPHY
OF
THE NATIONAL RESEARCH COUNCIL OF JAPAN

Published by

THE NATIONAL RESEARCH COUNCIL OF JAPAN
TOKYO, 1940

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Some Additional Notes on the Japanese Appendicularian Fauna

By

Takasi Tokioka

Seto Marine Biological Laboratory

(With 22 Text-figures)

Our knowledge of the Japanese Appendicularian fauna is due solely to Aida's work (1907). This deals with 12 species of which two (*Oik. cornutogastra* and *Oik. microstoma*) are questionable ones; the remaining 10: 1 *Kowalevskaia*, 3 *Fritillaria*, 4 *Oikopleura*, 1 *Megalocercus* and 1 *Stegosoma* are apparently valid. My study has added to this list 4 *Oikopleura*, 1 *Chunopleura*, 7 *Fritillaria* (5 species+2 forms), 1 *Tectillaria* and 1 *Appendicularia*. In the following pages are given some notes on the occurrence and systematical points of these 24 (22 species+2 forms) Japanese Appendicularians.

I am very grateful to Profs. T. Komai and T. Aida for their valuable advices and incessant encouragements given me throughout this study. Mr. Keitaro Uchida of The Fishery Experiment Station in Husan and Messrs. H. Tanaka and T. Suzuki of the Mitsui Institute of Marine Biology for their kind gift of specimens or help in collecting the material. To all these gentlemen I express here my hearty thanks.

1. *Oikopleura* (*Coecaria*) *longicauda* (Vogt), 1854

Oikopleura velifera, Langerhans, 1880.

Oikopleura velifera+*Oikopleura spissa*, Lohmann, 1892.

Oikopleura longicauda, Lohmann, 1896 b, 1900, 1909, 1931; Lohmann & Bückmann, 1926; Aida, 1907; Ihle, 1908 a; Krüger, 1912; Essenberg, 1926; Vernières, 1933.

Oikopleura (*Coecaria*) *longicauda*, Lohmann, 1933.

This is the commonest species in the warm oceanic waters, being distributed very widely and densely; they are fished occasionally from bays or inlets mingled with *Oik. dioica*.

Four specimens were obtained by Mr. R. Yoshi from the waters

near Etrohu-Sima (Kurile Islands) in the summer of 1932. Several specimens coloured scarlet or dark violet were observed at Susaki, Prov. Izu, and at Seto, Prov. Kii.

2. *Oikopleura (Coecaria) fusiformis* Fol, 1872

(Figs. 1, 2)

Oikopleura fusiformis, Langerhans, 1880; Lohmann, 1892, 1896 a b; 1900, 1909; Ihle, 1908 a; Krüger, 1912; Essenberg, 1926; Vernières, 1933.

Oikopleura fusiformis + *Oikopleura cornutogastra*, Aida, 1907; Lohmann & Bückmann, 1926; Lohmann, 1931.

Oikopleura cornutogastra, Bückmann, 1924.

Oikopleura (Coecaria) fusiformis + *Oikopleura (Coecaria) cornutogastra*, Lohmann, 1933.

This pure oceanic form which inhabits warm waters is common, but less than the preceding species. *Oikopleura cornutogastra* Aida seems to be a form of *Oik. fusiformis*, since these two species conform very well with each other in the morphology of the trunk as well as in the narrow appearance of the tail muscular band; the only distinction being in the shape of the blind sac of the left stomach lobe which shows, however, a wide range of variation in *Oik. fusiformis* as shown in Fig. 2. Furthermore it is to be noted that the mosaic arrangement of the oikoplast epithelial cells (Lohmann & Bückmann 1926) of *Oik. cornutogastra* collected during the "Deutsche Südpolar Expedition" is exactly like that found in *Oik. fusiformis* (Fig. 1) from the Japanese waters. I found in two specimens referable to *Oik. cornutogastra* collected from the surface waters off Minabe, Prov. Kii, on

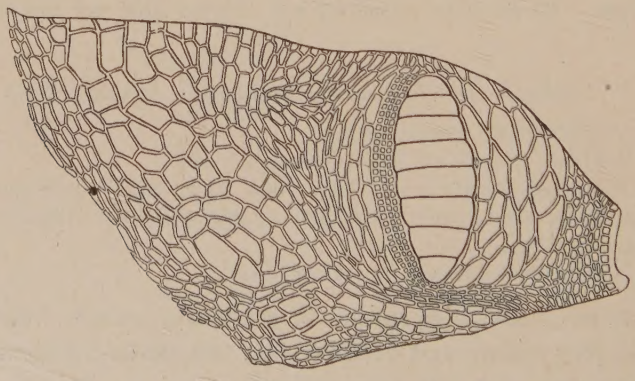

Fig. 1. *Oik. fusiformis*, oikoplast epithelium, from the right side. ×80.

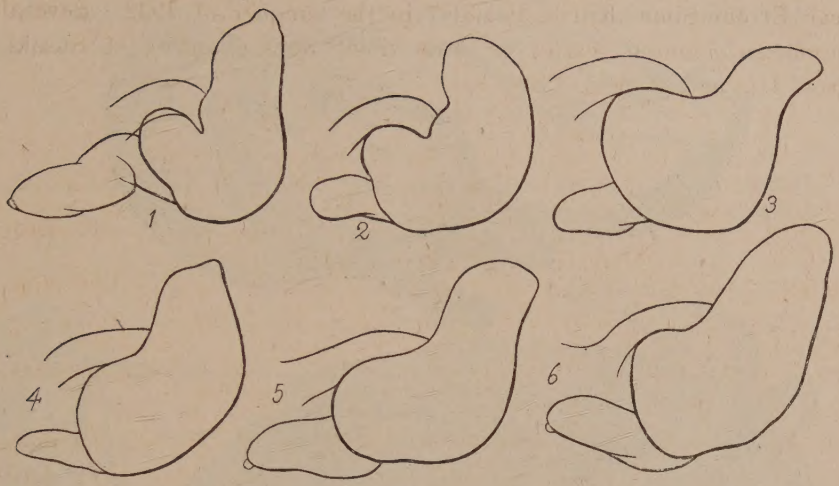

Fig. 2. *Oik. fusiformis,* the shape of the blind sac of the left stomach lobe. × ca. 50.

20/XI, '38, the characteristic appearance of the blind sac of the left stomach lobe. These specimens, however, showed no clear distinction from the typical *Oik. fusiformis.*

3. *Oikopleura (Coecaria) intermedia* Lohmann, 1896

(Fig. 3)

Oikopleura intermedia, Lohmann, 1896 b, 1909, 1931.
Oikopleura microstoma, Aida, 1907; Ihle, 1908 a.
Oikopleura tortugensis, Brooks & Kellner, 1908.
Oikopleura intermedia + *Oikopleura microstoma,* Lohmann & Bückmann, 1926.
Oikopleura (Coecaria) intermedia + *Oikopleura (Coecaria) microstoma,* Lohmann, 1933.

Several specimens were collected from the waters along the western coast of Kyûsyû by a surveying ship of the Fishery Experiment Station in Husan during 1936–38. Besides these, two specimens from the surface waters off Minabe, Prov. Kii, on 20/XI, '38 were examined.

This species resembles closely *Oik. longicauda* in the appearance of the blind sac of the left stomach lobe. However, the former has neither hood nor any conspicuous prominence of the ventral epithelium in front of the anus (ventraler Hautanhang, Lohmann 1892) which characterizes *Oik. longicauda.* On the other hand, *Oik. intermedia* is provided distinctly with Eisen's oikoplast epithelium which is lacking in *Oik. longicauda. Oikopleura microstoma* Aida seems to be synony-

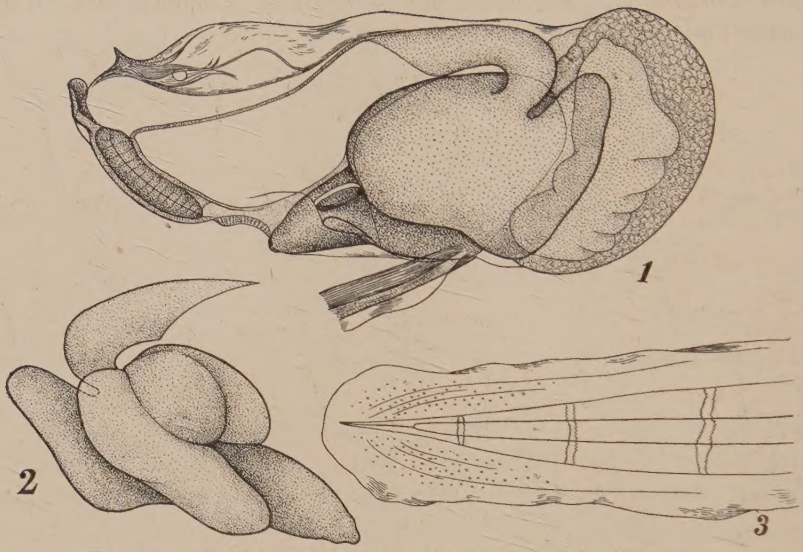

Fig. 3. *Oik. intermedia*; 1—trunk from the left side ×40, 2—alimentary canal from the right side ×40, 3—tip of the tail. ×15.

mous with the present species, since these two species conform exactly with each other in the structure of the trunk and tail (breadth of the musculature etc.).

4. *Oikopleura* (*Vexillaria*) *dioica* Fol, 1872

Oikopleura dioica, Langerhans, 1880; Lohmann, 1892, 1896 a b, 1900, 1909, 1931; Lohmann & Bückmann, 1926; Aida, 1907; Krüger, 1912; Essenberg, 1926; Vernières, 1933; Yamada, 1933.
Oikopleura (*Vexillaria*) *dioica*, Lohmann, 1933.

This is the commonest species found in the Yellow Sea, the Inland Sea, as well as in bays or inlets along the coasts of the whole Honsyû, Kyûsyû and Hokkaidô; it is abundant throughout the year. The number of the subchordal cells in the tail is two, though it may be 1 or 3 in rare cases.

5. *Oikopleura* (*Vexillaria*) *rufescens* Fol, 1872

Oikopleura rufescens, Langerhans, 1880; Lohmann, 1892, 1896 b, 1909, 1931; Lohmann & Bückmann, 1926; Aida, 1907; Ihle, 1908 a; Krüger, 1912; Essenberg, 1926.
Oikopleura (*Vexillaria*) *rufescens*, Lohmann, 1933.

An inhabitant of the warm oceanic waters. Common, but rarer than *Oik. longicauda* and *Oik. fusiformis*.

6. *Oikopleura (Vexillaria) cophocerca* Gegenbaur, 1885

(Fig. 4)

Oikopleura cophocerca, Lohmann, 1892, 1896 b, 1909, 1931; Lohmann & Bückmann, 1926; Ihle, 1908 a; Krüger, 1912; Essenberg, 1926; Vernières, 1933.

Oikopleura (Vexillaria) cophocerca, Lohmann, 1933.

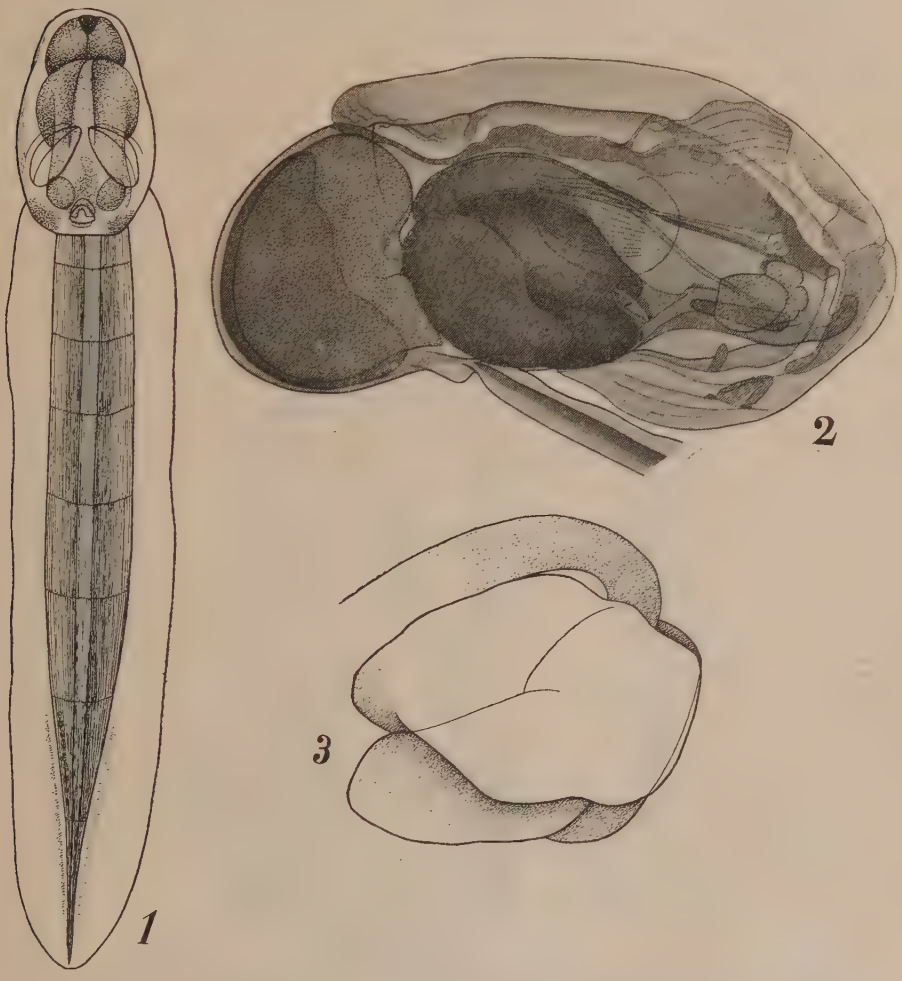

Fig. 4. *Oik. cophocerca;* 1—entire animal ×20, 2—trunk from the right side ×50, 3—alimentary canal from the left side ×80.

Rather rare; several specimens were collected from the waters off Susaki, Prov. Izu, and Seto, Prov. Kii. In these specimens the number of the subchordal cells is usually 9 (6–12) in the mature state.

7. *Oikopleura* (*Vexillaria*) *albicans* (Leuckart), 1853

(Fig. 5)

Oikopleura albicans, Lohmann, 1896 b, 1909, 1931; Lohmann & Bückmann, 1926; Krüger, 1912; Essenberg, 1926; Vernières, 1933.
Oikopleura (*Vexillaria*) *albicans*, Lohmann, 1933.

A single specimen was collected from the surface waters off Sionomisaki in the summer of 1938.

Fig. 5. *Oik. albicans*; 1—entire animal × 12, 2—trunk from the left side × 35, 3—alimentary canal from the right side × 35.

8. *Oikopleura* (*Vexillaria*) *labradoriensis* Lohmann, 1892

(Fig. 6)

Oikopleura labradoriensis, Lohmann, 1892, 1896 a b, 1900, 1905; Lohmann & Bückmann, 1926; Krüger, 1912; Essenberg, 1926.
Oikopleura (*Vexillaria*) *labradoriensis*, Lohmann, 1933.
(*Oikopleura chamissonis*?).

Common in the cold oceanic waters, and collected from the Japan Sea and northern waters of Japan. The number of the subchordal cells is 17–25 in many specimens. It is not impossible that *Oikopleura chamissonis* Mertens 1831, found from the Bering Strait is identical with the present species, as already pointed out by Lohmann.

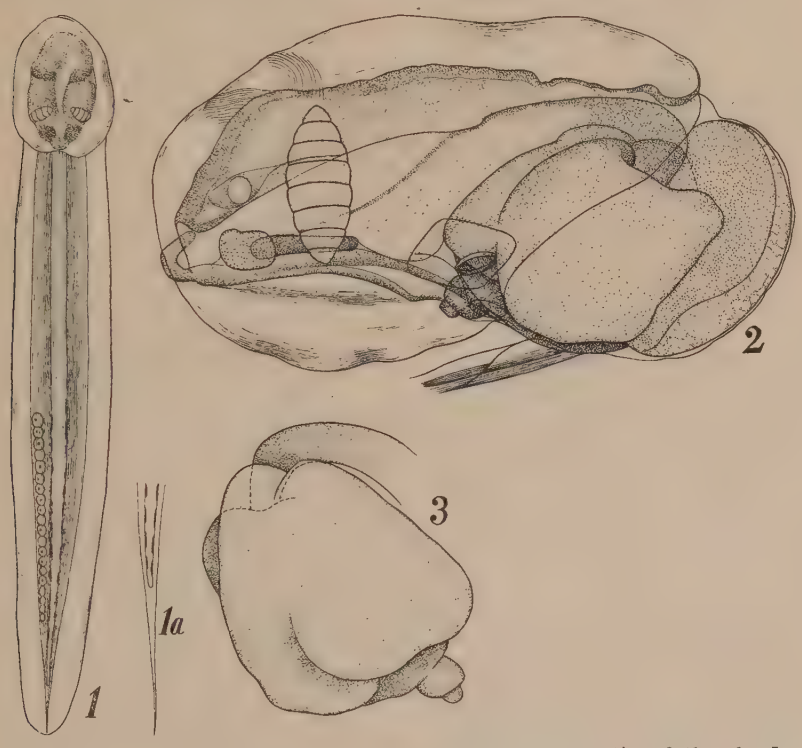

Fig. 6. *Oik. labradoriensis;* 1—entire animal ×15, 1 a—tip of the chorda, 2—trunk from the left side ×70, 3—alimentary canal from the right side ×70.

9. *Megalocercus huxleyi* (Ritter), 1905

Oikopleura huxleyi, Ritter & Byxbee, 1905.
Oikopleura megastoma, Aida, 1907.

Megalocercus huxleyi, IHLE, 1908 a b; LOHMANN & BÜCKMANN, 1926; LOHMANN, 1931, 1933.
Megalocercus sp.?, OKA, 1915.

This large species is not rare in the Japanese waters. Many specimens were collected from the surface waters off Susaki, Prov. Izu, Seto, Prov. Kii, Suruga Bay and also from the south-east waters of Tyôsen.

10. *Stegosoma magnum* (LANGERHANS), 1880

Oikopleura magna, LANGERHANS, 1880.
Stegosoma pellucidum, LOHMANN, 1892.
Stegosoma magnum, LOHMANN, 1896 b, 1909, 1931, 1933; LOHMANN & BÜCKMANN, 1926; AIDA, 1907; IHLE, 1908 a, 1929; KRÜGER, 1912.
Stegosoma magnum + *Megalocercus diegensis*, ESSENBERG, 1926.

This species occurs frequently, though not in abundance, in the warm oceanic waters off Susaki, Prov. Izu, Seto, Prov. Kii, and in the south-east waters of Tyôsen.

11. *Chunopleura microgaster* LOHMANN, 1914

(Fig. 7)

Chunopleura microgaster, LOHMANN, 1914, 1931, 1933; LOHMANN & BÜCKMANN, 1926.

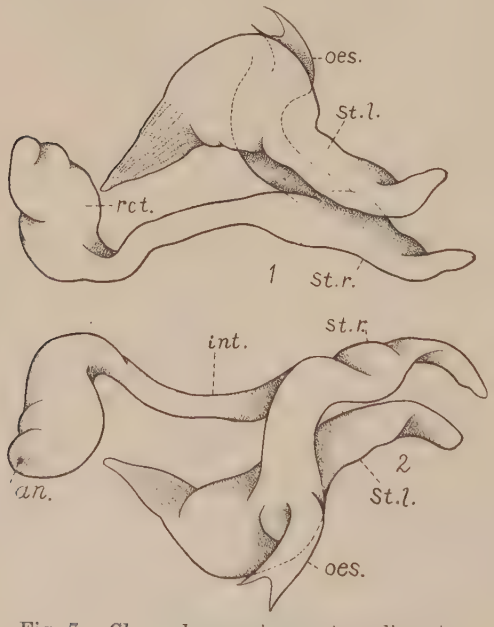

Fig. 7. *Chunopleura microgaster*, alimentary canal. 1—left ventral side, 2—right dorsal side × 70.

A specimen was found in the plankton sample hauled in Suruga Bay in the summer of 1937. The body length is ca. 4 mm, the tail length 13.3 mm. The anterior pharyngeal portion, the posterior germinal portion containing gonads and also the tail were mutilated considerably, but close examination of the alimentary canal (Fig. 7) enabled me to identify the present specimen as *Chunopleura microgaster*, a rare oikopleurid reported once by LOHMANN (1914) from the east Indian Ocean.

Endostyle short? A

packet of glandular cells behind the endostyle? Row of ciliated cells around the oral area?

12. *Fritillaria* (*Acrocercus*) *haplostoma* Fol, 1872

Fritillaria haplostoma, Fol, 1874; Lohmann, 1896 b, 1909, 1931; Lohmann & Bückmann, 1926; Aida, 1907; Ihle, 1908 a; Essenberg, 1926; Vernières, 1933.
Fritillaria (*Acrocercus*) *haplostoma*, Lohmann, 1933.

A common species in the warm oceanic waters. This species was fished from the inlet waters of Mori Harbour in Tanabe Bay mingled with *Oik. dioica*.

13. *Fritillaria* (*Acrocercus*) *formica* Fol, 1872

(Fig. 8)

Fritillaria formica, Langerhans, 1880; Lohmann, 1892, 1896 b, 1909, 1931; Lohmann & Bückmann, 1926; Ihle, 1908 a; Essenberg, 1926; Vernières, 1933.
Fritillaria (*Acrocercus*) *formica*, Lohmann, 1933.

Forma *digitata* Lohmann & Bückmann, 1926

Fritillaria formica forma *digitata*, Lohmann & Bückmann, 1926; Lohmann, 1931; Vernières, 1933.

Rather rare. Several specimens which seem to be of *digitata* form were collected in the following stations: off Susaki, Prov. Izu, Seto, Prov. Kii, and south-east coast of Tyôsen.

14. *Fritillaria* (*Acrocercus*) *fraudax* Lohmann, 1896

(Fig. 9)

Fritillaria glandulifera part, Lohmann, 1892.
Fritillaria fraudax, Lohmann, 1896 b, 1909, 1931; Lohmann & Bückmann, 1926; Bückmann, 1924.
Fritillaria (*Acrocercus*) *fraudax*, Lohmann, 1933.

Two specimens were found in the plankton sample hauled in the surface waters off Gobô, Prov. Kii, on 20/XI, '38.

15. *Fritillaria* (*Eurycercus*) *pellucida* (Busch), 1851

Fritillaria furcata, Langerhans, 1880; Lohmann, 1892.
Fritillaria pellucida, Lohmann, 1896 b, 1909, 1931; Lohmann & Bückmann, 1926; Aida, 1907; Ihle, 1908 a; Essenberg, 1926; Vernières, 1933.
Fritillaria (*Eurycercus*) *pellucida*, Lohmann, 1933.

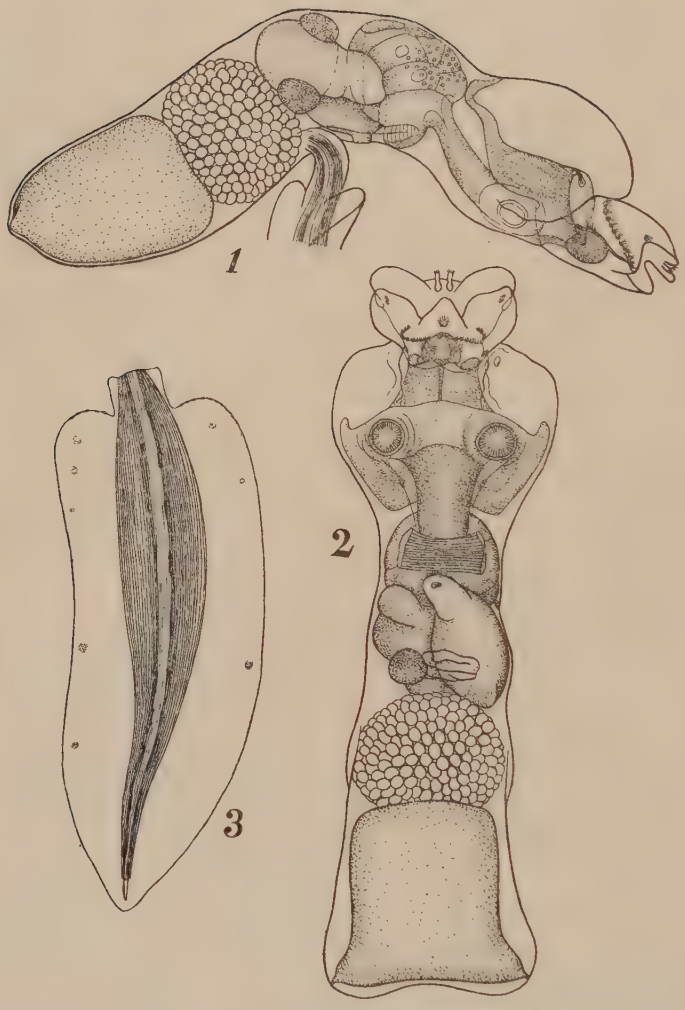

Fig. 8. *Frit. formica;* 1—trunk from the right side ×50, 2—trunk from the ventral side ×50, 3—tail ×35.

The commonest *Fritillaria* in the warm oceanic waters of Japan.

16. *Fritillaria* (*Eurycercus*) *borealis* Lohmann, 1896

(Figs. 10–14)

Fritillaria borealis; Lohmann, 1896 a, 1900, 1905, 1909, 1928, 1931; Lohmann & Bückmann, 1926; Ihle, 1908 a; Vernières, 1933.
Fritillaria borealis + *Fritillaria sargassi,* Lohmann, 1896 b.
Fritillaria ritteri, Aida, 1907.

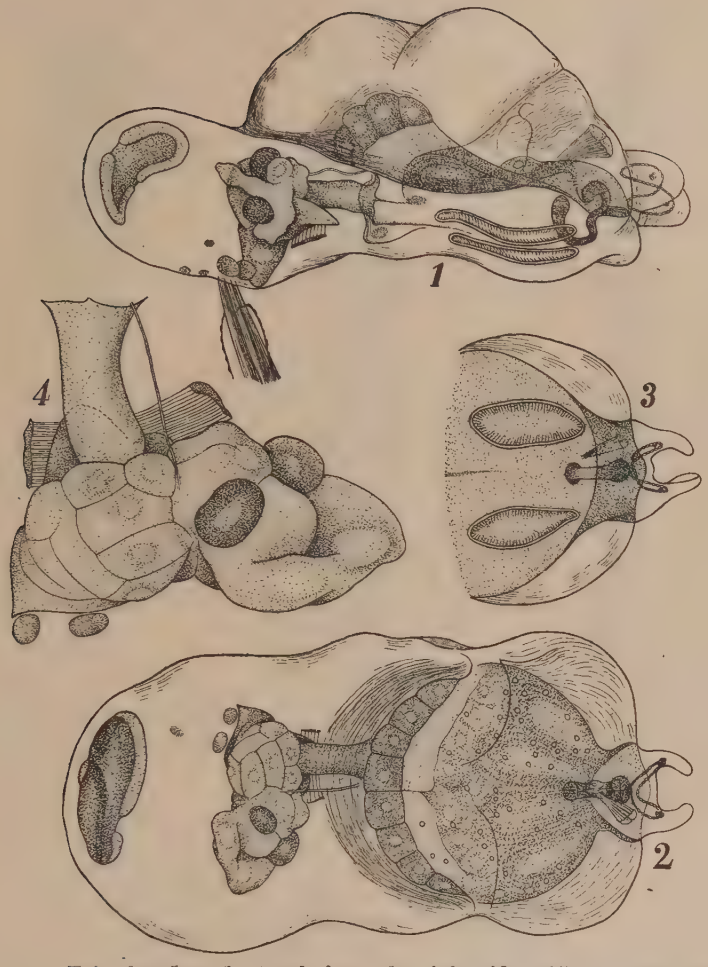

Fig. 9. *Frit. fraudax;* 1—trunk from the right side × 85, 2—trunk from the dorsal side × 85, 3—ventral side of the pharyngeal portion × 85, 4—alimentary canal from the dorsal side × 180.

Fritillaria borealis + *Fritillaria sargassi* + *Fritillaria ritteri*, ESSENBERG, 1926.
Fritillaria (*Eurycercus*) *borealis*, LOHMANN, 1933.

The conspicuous variability of the body form in this species has been fully discussed by LOHMANN. The following remarks, however, do not seem to be superfluous in dealing with the Japanese material.

In boreal specimens the breadth of the tail musculature (Fig. 10) is narrow, being usually 3–4 times the chorda breadth, whereas in warm oceanic specimens it is very broad, reaching nearly 7–8 times

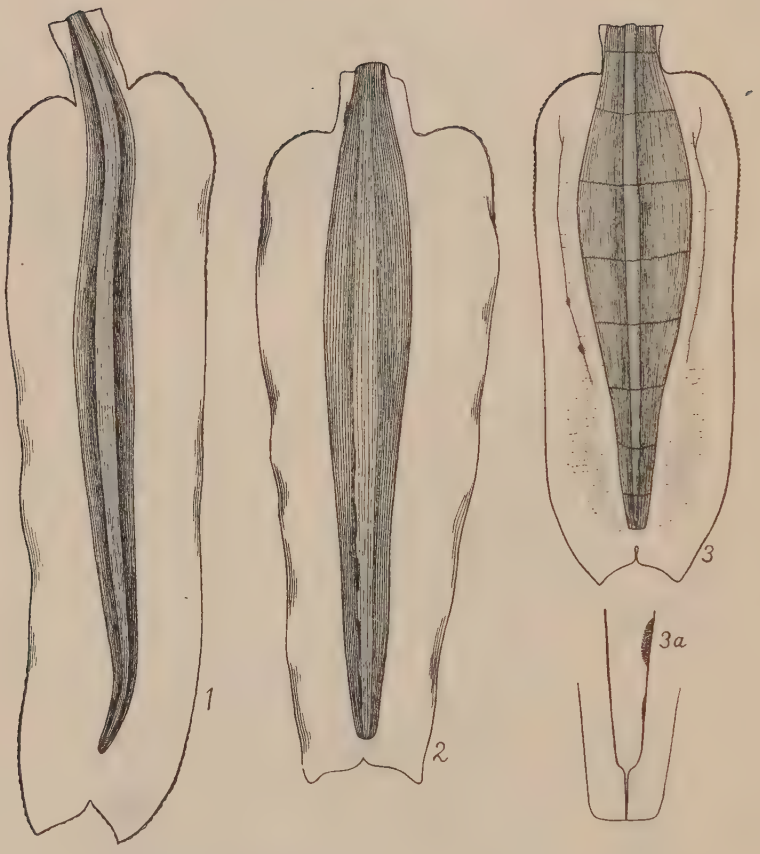

Fig. 10. *Fruit. borealis,* tail; 1—Forma *typica* × 70, 2—Forma *intermedia* × 85, 3—Forma *sargassi* × 25, 3 a—tip of the tail musculature of forma *sargassi.*

the chorda breadth. These two extremities are united by a continuous series of intermediate grades met with among both boreal and warm oceanic materials. To a casual observation the boreal specimens appear to have a more pointed end of the tail musculature than the warm oceanic specimens. However, a closer examination reveals that there are a number of intermediate forms, and the distinction of the 'subspecies' *acuta* and *truncata* is quite obsolete. Next, the outline of the anterior end of the tail fin is considered as a distinctive characteristic between *truncata ritteri* and *truncata sargassi,* but this characteristic also does not seem to be constant, being highly changeable by preservation.

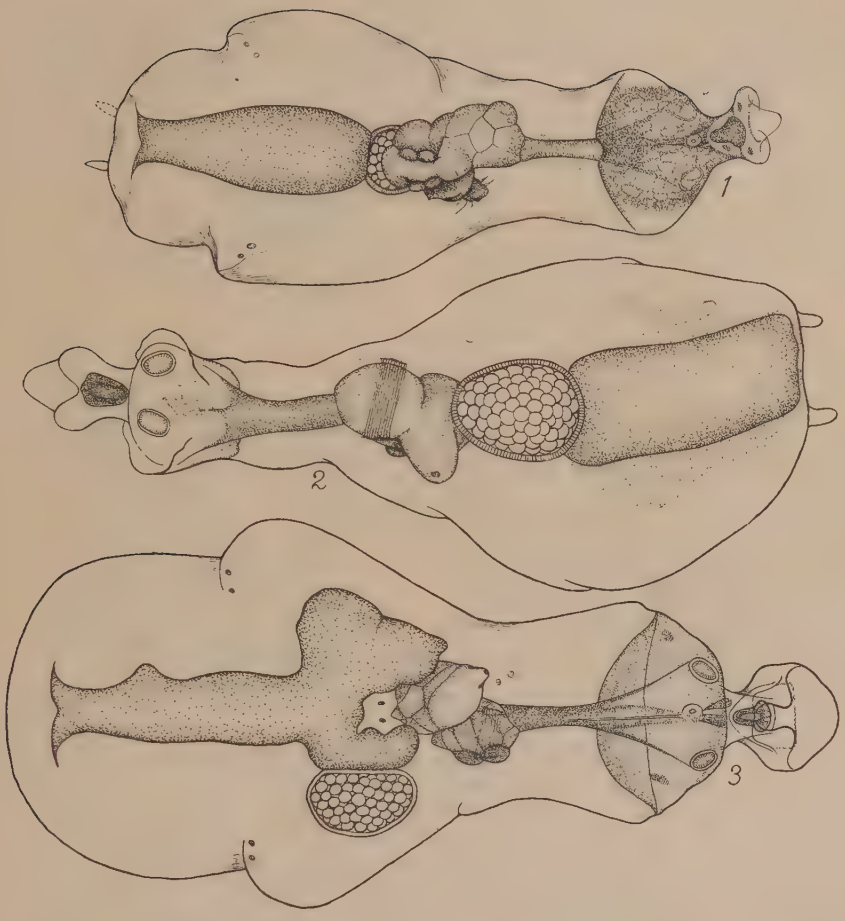

Fig. 11. *Frit. borealis,* trunk; 1—Forma *typica,* dorsal ×70, 2—Forma *intermedia,* ventral ×85, 3—Forma *sargassi,* ventral ×50.

The shape of the testis and the relative position of the ovary and testis (Fig. 11) are good distinctive characteristics. In the boreal and intermediate specimens the testis is elongate and has a simple outline, and is located just behind the ovary on the median line of the trunk. In the warm oceanic specimens with broad tail musculature on the other hand, the anterior end of the testis is forked and the ovary is situated on the left side of the trunk. The bi-horned appearance of the posterior end of the testis seems to be a general characteristic of this species.

The number of the large intestinal gland cells (Fig. 12) is variable.

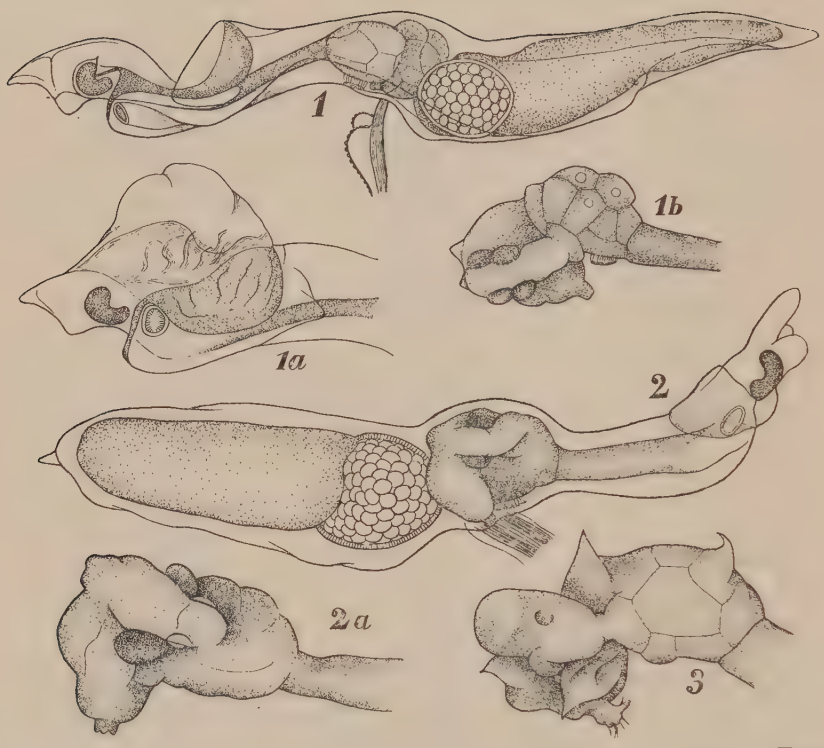

Fig. 12. *Frit. borealis;* 1—Forma *sargassi,* left side of the trunk ×50; 1 a—Forma *sargassi,* left side of the pharyngeal portion with hood ×50; 1 b—Forma *sargassi,* right dorsal side of the alimentary canal ×80; 2—Forma *intermedia,* right side of the trunk ×90; 2 a —Forma *intermedia,* alimentary canal from the right side ×80; 3—Forma *typica,* dorsal side of the alimentary canal ×145.

Usually, there are four (two on each side of the intestine) gland cells in the warm oceanic specimens which have broad tail musculature. The boreal specimens have similar gland cells, but they consist of a large and a small gland cells situated on each side, or there is a single cell on each side which may be rudimentary; the intermediate specimens have 2~4 gland cells. The orientation of the oesophagus is usually median in all Japanese specimens, but in the warm oceanic specimens having the forked testis it may be shifted slightly to the left side. *Frit. borealis truncata ritteri* may be separated from *Frit. borealis truncata sargassi* by the median orientation of the oesophagus, although such a character is subject to wide range of variation at least in *Frit. pellucida.*

The presence of a pair of small protuberances at the posterior end of the trunk and a sinus on each lateral side of the germinal portion of the trunk, with two small gland cells in the neighbourhood, is considered as a general characteristic of this species. The general shape of the posterior trunk is variable according to the volume of the gonads and the state of preservation. The hood can rarely be observed.

In short, the Japanese specimens may be classified into the following three forms:

a. Forma *typica* (Lohmann), 1900

Fritillaria borealis, Lohmann, 1896 a b; Essenberg, 1926.
Fritillaria borealis typica, Lohmann, 1900, 1928.
Fritillaria borealis forma *typica*, Lohmann, 1905; Lohmann & Bückmann, 1926.
Fritillaria borealis acuta typica, Lohmann, 1931.

Tail musculature narrow, outline of testis simple. 2 rudimentary ~4 distinct intestinal gland cells. Ovary median.

Common and abundant in the northern waters of the Japan Sea.

b. Forma *intermedia* Lohmann, 1905

Fritillaria borealis forma *intermedia*, Lohmann, 1905; Lohmann & Bückmann, 1926.
Fritillaria borealis truncata intermedia, Lohmann, 1931.
Fritillaria borealis truncata forma *intermedia*, Vernières, 1933.
(*Fritillaria messanensis* Lohmann?).

Tail musculature intermediate. Outline of testis simple, ovary median. 2~2 distinct+2 rudimentary~4 intestinal gland cells.

This form is fished in the Japan Sea mingled with forma *typica*, while in the waters off the west coast of Kyûsyû and along the Pacific coast of Honsyû it is mingled with the next form. In a specimen obtained near Seto, Prov. Kii, the posterior end of the tail fin is not cut in as shown in Fig. 13.

c. Forma *sargassi* (Lohmann), 1896

Fritillaria sargassi, Lohmann, 1896 b.
Fritillaria borealis var. *sargassi*, Lohmann, 1900.
Fritillaria borealis forma *sargassi*, Lohmann, 1905.
Fritillaria ritteri, Aida, 1907.
Fritillaria borealis forma *ritteri*, Ihle, 1908 a.
Fritillaria borealis forma *sargassi*+*Fritillaria borealis* forma *ritteri*, Lohmann & Bückmann, 1926.

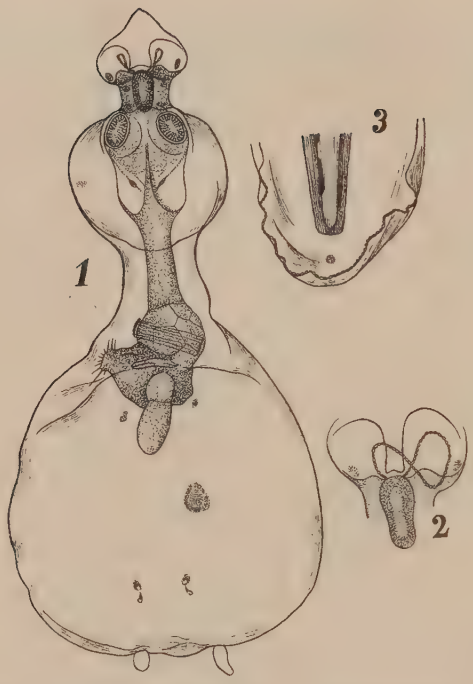

Fig. 13. *Frit. borealis* forma *intermedia* with abnormal tail; 1—trunk from the ventral side ×90, 2—ventral side of the oral area, 3—tip of the tail.

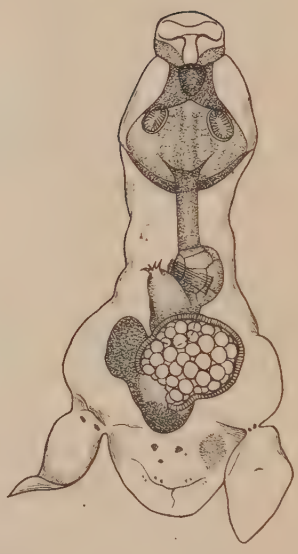

Fig. 14. *Frit. borealis* forma *sargassi*, abnormal specimen; trunk from the ventral side ×90.

Fritillaria sargassi + *Fritillaria ritteri*, Essenberg, 1926.
Fritillaria borealis truncata sargassi + *Fritillaria borealis truncata ritteri*, Lohmann, 1931.

Tail musculature very wide. Anterior end of testis forked, ovary on the left side of the trunk. 4 intestinal gland cells.

An inhabitant of the warm oceanic waters; not abundant. A specimen from the neighbourhood of Seto, Prov. Kii, (Fig. 14) shows a very curious appearance in the posterior half of the trunk, in having a large protuberance beside each lateral sinus.

17. *Fritillaria* (*Eurycercus*) *megachile* Fol, 1872

(Fig. 15)

Fritillaria megachile, Langerhans, 1880; Lohmann, 1909, 1931; Lohmann & Bückmann, 1926; Ihle, 1908 a.
Fritillaria (*Eurycercus*) *megachile*, Lohmann, 1933.
(*Fritillaria dispara* Essenberg?).

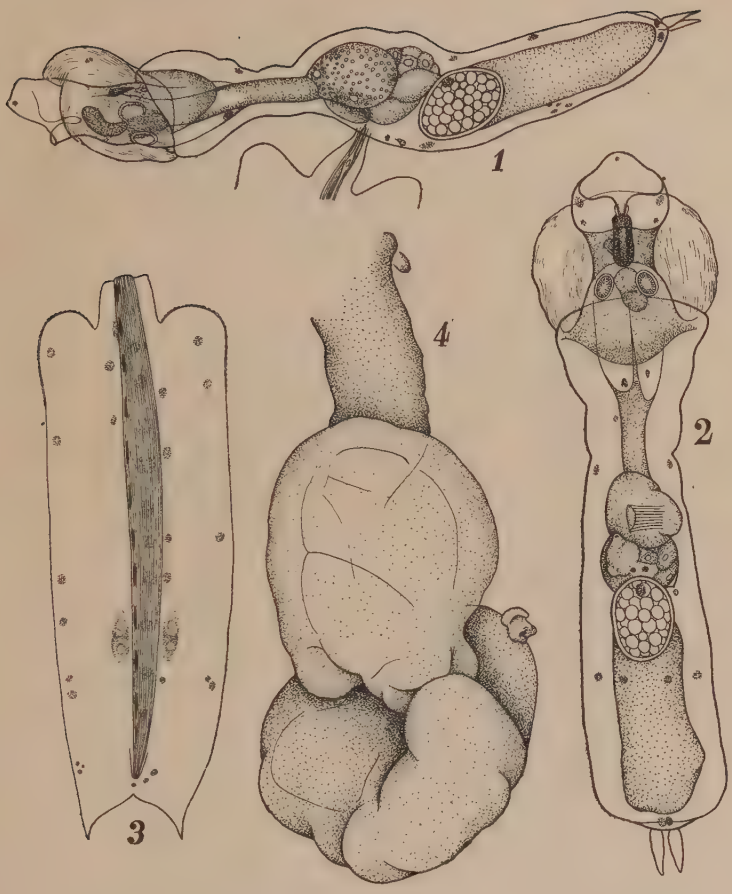

Fig. 15. *Frit. megachile;* 1—trunk from the left side × 40, 2—trunk from the ventral side × 40, 3—tail × 25, 4—alimentary canal from the dorsal side × 45.

A rare species of the warm oceanic waters. The hood and small posterior protuberances at the posterior end of the trunk as well as two pairs of large gland cells on the tail fin are often missing even in well-preserved specimens. The hood when present covers the whole pharyngeal portion except the anterior part of the dorsal lip.

18. *Fritillaria (Eurycercus) tenella* Lohmann, 1896

(Figs. 16–17)

Fritillaria tenella, Lohmann, 1896 b, 1909, 1931; Lohmann & Bückmann, 1926; Ihle, 1908 a.

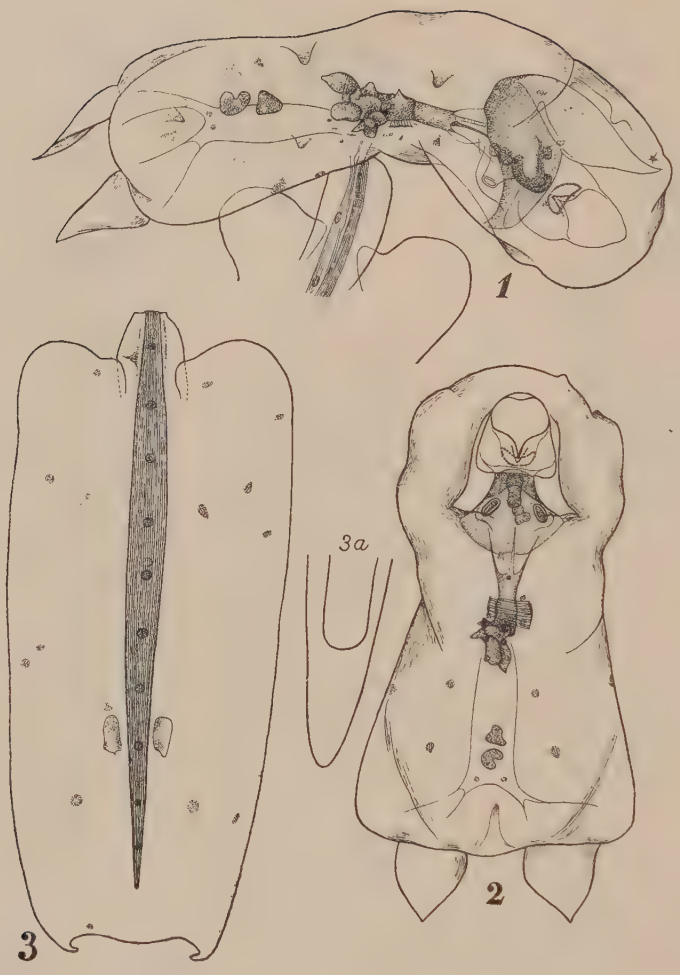

Fig. 16. *Frit. tenella;* 1—trunk from the right side ×30, 2—trunk from the ventral side ×25, 3—tail ×25, 3 a—tip of the chorda.

Fritillaria (*Eurycercus*) *tenella*, LOHMANN, 1933.
(*Fritillaria scillae* LOHMANN?).

A few specimens were fished from the surface waters off Susaki, Prov. Izu. The configuration of the intestine apparently shows a great deal of variation. The intestinal gland cells are present in some individuals, but entirely absent in others. Many wall cells of the intestine project into the body cavity, as IHLE (1908) describes on his material of the Siboga-Expedition. The pharyngeal gland cells behind

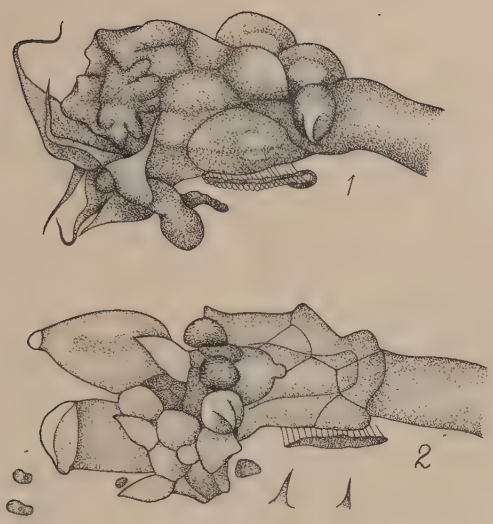

Fig. 17. *Frit. tenella,* alimentary canals from the right side ×130.

the endostyle are 2–3.

It seems to me that *Fritillaria scillae* LOHMANN 1898 is identical with the present species. Both species have the pharyngeal gland cells. The alimentary canal and gonad as well as the tail are closely similar in these two species. The presence or absence of the hood can not be taken as a distinctive characteristic of *Fritillaria,* since the structure is highly liable to damage in *Frit. megachile* and *Frit. borealis.*

19. *Fritillaria* (*Eurycercus*) *venusta* LOHMANN, 1896

(Fig. 18)

Fritillaria venusta, LOHMANN, 1896 b, 1909; LOHMANN & BÜCKMANN, 1926; ESSENBERG?, 1926.

Fritillaria (*Eurycercus*) *venusta,* LOHMANN, 1933.

Only one specimen was found among the Copelata collected from the surface waters off Gobô, Prov. Kii, on 20/XI, '38. 4 pharyngeal gland cells are present. The wall cells of the intestine have no conspicuous projections. A pair of large gland cells are present on the tail as in many other *Eurycercus.* The chordal cells are distinguishable in the Japanese specimen as shown in Fig. 18–3. The posterior end of the tail fin conforms well with LOHMANN's descriptions (1896 b).

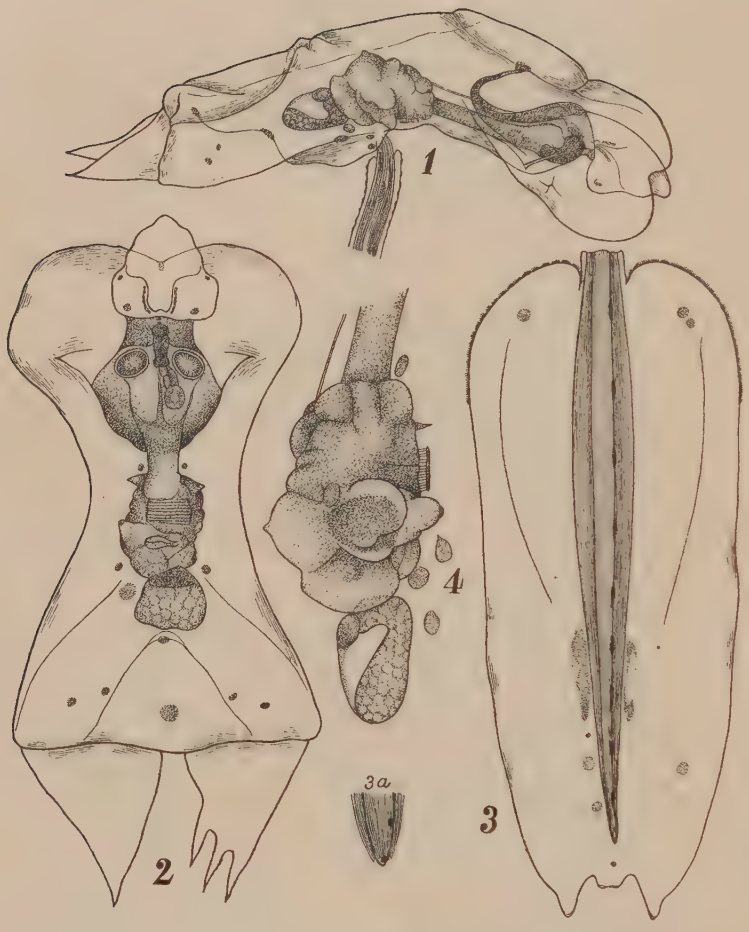

Fig. 18. *Frit. venusta*; 1—trunk from the right side ×85, 2—trunk from the ventral side ×85, 3—tail ×70, 3 a—tip of the tail musculature, 4—alimentary canal from the right side ×180.

20. *Tectillaria fertilis* (Lohmann), 1896

(Figs. 19, 20)

Fritillaria fertilis, Lohmann, 1896 b; Bückmann, 1924.
Tectillaria fertilis, Lohmann & Bückmann, 1926; Lohmann, 1931, 1933; Vernières, 1934.

Several specimens were collected from the south-east waters of Tyôsen, the surface waters off Seto, Prov. Kii, and Susaki, Prov. Izu.

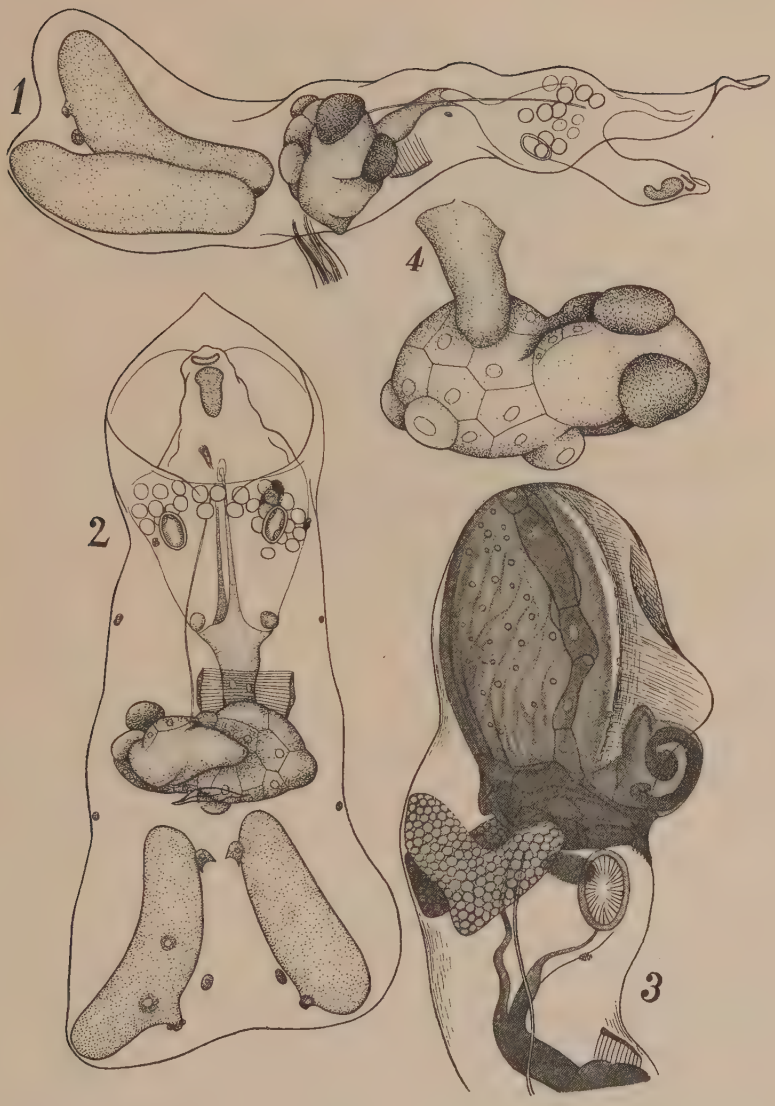

Fig. 19. *Tect. fertilis*; 1—trunk from the right side × 60, 2—trunk from the ventral side × 60, 3—right side of the pharyngeal portion × 90, 4—alimentary canal from the dorsal side × 250.

A conspicuous nerve ganglion (Fig. 20, g_1) is found on the outer side of each spiracle. This ganglion seems to be provided with some short nerves going to the spiracle besides the anterior and posterior offshoots, the latter of which (n) can be traced distinctly to the alimentary canal

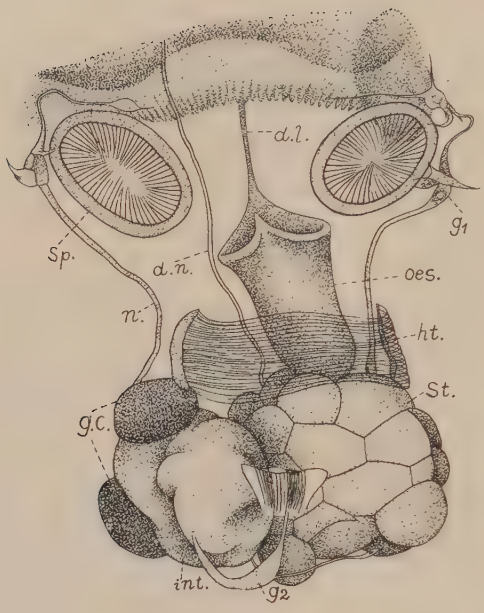

Fig. 20. *Tect. fertilis*, ventral side of the pharyngeal portion ×250.

where its course becomes obscure. The posterior end of the tail fin is cut-in widely? A pair of gland cell complexes are present on the tail fin?

21. *Kowalevskaia tenuis* Fol, 1872

Kowalevskia tenuis, Fol, 1874; Lohmann, 1892, 1896 b, 1909, 1914; Aida, 1907; Essenberg, 1926.
Kowalewskaia tenuis, Lohmann & Bückmann, 1926.
Kowalevskaia tenuis, Lohmann, 1933; Vernières, 1933.

Two specimens were obtained from the south-east waters of Tyôsen.

22. *Appendicularia sicula* Fol, 1874

(Fig. 21)

Appendicularia sicula, Fol, 1874; Langerhans, 1880; Lohmann, 1892, 1896 b, 1909, 1931; Lohmann & Bückmann, 1926; Essenberg, 1926.

A rare species. Only two specimens were found among the plankton collections hauled near Seto, Prov. Kii.

Fig. 21. *App. sicula*, 1—trunk from the left side ×180, 2—tail ×85.

Concluding Remarks

The Japanese Appendicularians may be divided into three groups: 1) the cold oceanic water forms, 2) the warm oceanic water forms, and 3) the inlet or brackish water forms. The first group comprises *Oik. labradoriensis* and *Frit. borealis* forma *typica* which are found in the northern waters of Japan, forming sometimes the *'Oikopleura* or *Fritillaria*-water'. Most of the other species, excepting *Oik. dioica,* belong to the second group, and are distributed along the Black Current (Kuro-Sio). *Oik. longicauda, Oik. fusiformis, Frit. pellucida,* and *Frit. haplostoma* are the commonest species, followed by *Oik. rufescens, Oik. cophocerca, Meg. huxleyi, Steg. magnum, Frit. formica,* and *Frit. borealis* forma *intermedia~sargassi. Oik. albicans, Frit. megachile, Frit. tenella, Frit. venusta, Frit. fraudax, Tect. fertilis, Chun. microgaster, Kow. tenuis* and *App. sicula* all are the rare forms. Aida (1907) states that *Kow. tenuis* is a common visitor to the Pacific coast of Japan, but in my experience this species seems to be one of the rare species. It seems to me that Aida had a chance to encounter a large swarm of *Kow. tenuis* which occur only sparsely in the north-west Pacific. *Oik.*

dioica is common in the inlet or brackish waters of Japan, forming frequently a dense *'Oikopleura*-water'.

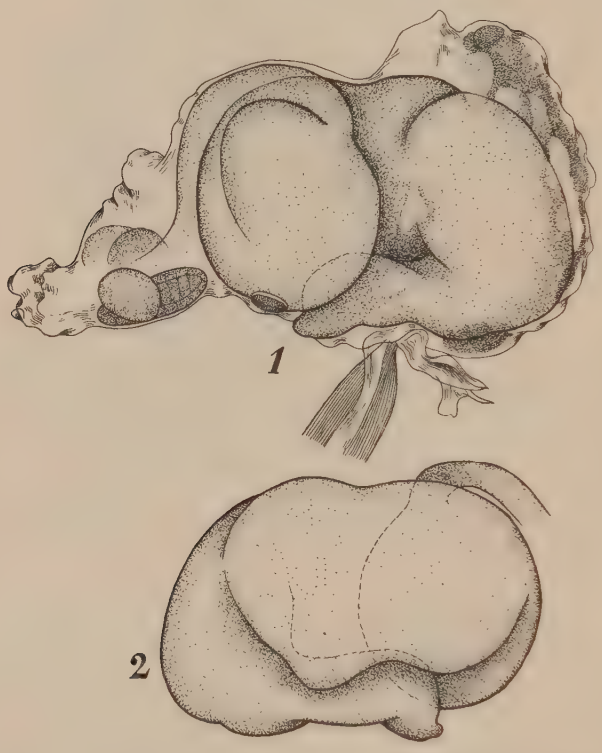

Fig. 22. Undeterminable *Oikopleura* (*Vexillaria*)-specimen; 1—trunk from the left side × 70, 2—alimentary canal from the right side × 70.

Besides the species mentioned above, two mutilated undeterminable specimens are at hand, of which one is a *Pelagopleura*-like individual found in a plankton sample hauled in the south-east waters of Tyôsen. The short distance between the posterior end of the endo-style and the anus brings this specimen close to *Pelagopleura haranti* VERNIÈRES. The other specimen (Fig. 22, 1.1 mm in trunk length) belongs to *Oikopleura* (*Vexillaria*) and shows some resemblance to *Oik. dioica, Oik. rufescens* and *Oik. parva* LOHMANN; it shows the closest affinity to the last named species.

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Abbreviations

an.....anus.
d.l. .....dorsal lamina.
d.n.....dorsal nerve.
g_1 .....ganglion near the spiracle.
g_2 .....ganglion at the base of the tail.
g.c.....intestinal gland cell.
ht. .....heart.
int.....intestine.
n.....nerve.
oes.....oesophagus.
rect.....rectum.
sp. .....spiracle.
st.....stomach.
st.l. ....left stomach lobe.
st.r. ....right stomach lobe.

Bio-Geographic Review on the Distribution of Crabs in Japanese Waters

By

Tune Sakai

Gihu-ken Women's Normal School

(With 3 Text-figures)

Contents

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III. Distribution in Japanese waters of the species, peculiar to the Indian Ocean.
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2. On the species inhabiting the extensive regions in the Indian Ocean.
IV. Distribution in Japanese waters of the species inhabiting the tropical Pacific Ocean.
V. Distribution of the species inhabiting the Far East.
1. Species common to Japan, China and Manchoukuo.
2. Endemic Japanese species.
VI. Distribution in Japanese waters of the species found in the northern cold districts of the Pacific Ocean.
VII. Cosmopolite species found in Japanese waters.
VIII. Conclusion.

I. Introduction

The distribution of crabs in Japanese waters has already been discussed by such authors as Doflein (1902), Balss (1924), and Yokoya (1933). These authors largely agree in admitting the influence of the two great ocean currents—the Kurosiwo or the warm current and the Oyasiwo or the cold current—upon the distribution of crabs in Japanese water, distinguishing three groups—the southern, northern, and endemic; the southern group include the species pro-

pagated from the southern tropical waters, and the northern group those from the northern cold regions of the Pacific Ocean. I quite agree with those authors in this point, but owing to the recent progress in taxonomic and zoo-geographic studies of crabs found in the Indo-Pacific including Hawaii, Australia, Singapore, India, Red Sea, and the east coast of Africa, a thorough revision of this thema seems needed.

The species of Japanese crabs hitherto known number about 675, referable to 253 genera and 25 families. Of these, about 420 seem to be elements from the tropical Indian, Malaysian, or Pacific waters. These southern forms are, in my opinion, from at least three sources; the extensive tropical Indo-Pacific, the Indian Ocean, and the tropical Pacific Ocean. Of about 240 local species which are restricted to the Far East, about 180 are endemic to Japan; these species form a peculiar local group in the fauna of the Far East, but mostly have their phylogenic origin in the southern forms, with a few of northern origin. The species from the northern Pacific Ocean and the cosmopolite ones also form important elements in the Japanese crab fauna, although they are very few in number.

This paper is practically an appendix to my monograph of the Japanese crabs published in 1936–1939 and gives a general bio-geographic revision of the rich Japanese crab fauna, although more precise investigations in future may bring a more accurate conclusion, especially for the four large elements referred to above and described further on.

Before going further, the author wishes to express his hearty gratitude to Dr. Taku Komai of the Kyoto Imperial University, Dr. Tamao Fukui of The Tokyo Bunrika Daigaku and Dr. Yaichiro Okada of The Tokyo Higher Normal School for their kind supervision and encouragement rendered during the study.

II. Distribution in Japanese waters of the genuine Indo-Pacific species

Amongst the vast number of species of crabs inhabiting the very extensive regions in the Indian Ocean, Malaysian Archipelago, and the Pacific Ocean, about 165 species, referable to 95 genera are distributed northward toward Japan. These species really show the widest distribution of crabs in the eastern hemisphere, ranging from the south and east coasts of Africa, Red Sea, Gulf of Persia, Andaman, Bengal, Malay Archipelago, north and east coasts of Australia, Poly-

nesia, Sandwich Islands, Melanesia, and also north toward the Japanese mainland. The species of the group which have their northern limit of distribution in Japanese waters are as follows:

Genuine Indo-Pacific species found in Japanese waters, showing their northern limit of distribution.

Species in systematic order.	Northern limit of distribution: (Pacific side)	(Continental side)
DROMIACEA		
Dromidiopsis dormia (LINNAEUS)	Kii Peninsula.	
Dromidia unidentata (RÜPPELL)	Kii Peninsula.	
Cryptodromia canaliculata STIMPSON	Sagami Bay.	
Dynomene hispida DESMAREST	Kii Peninsula.	
OXYSTOMATA		
Cryptosoma granulosum (DE HAAN)	Izu Peninsula	Nagasaki.
Mursia armata curtispina MIERS	Inuboe-zaki	Isikawa-ken.
Calappa hepatica (LINNAEUS)	Sagami Bay.	
C. calappa (LNNAEUS)	Sagami Bay.	
C. philargius (LINNAEUS)	Tokyo Bay	Nagasaki.
C. gallus (HERBST)	Izu Peninsula.	
Matuta banksii LEACH	Sagami Bay.	
M. lunaris (FORSKÅL)	Tokyo Bay	Toyama Bay.
Actaeomorpha erosa MIERS	Tosa Bay.	
Oreophorus (*Oreophorus*) *rugosus* STIMPSON	Kagosima Bay	Nagasaki.
Nursilia dentata BELL	Amami Ôsima.	
Myra fugax (FABRICIUS)	Tokyo Bay	Syônai Province.
Leucosia longifrons DE HAAN	Tokyo Bay	Syônai Province.
Lyreidus tridentatus DE HAAN	Inuboe-zaki	Syônai Province.
Ranina ranina (LINNAEUS)	Sagami Bay	Nagasaki.
OXYRHYNCHA		
Elamena truncata STIMPSON	Tokyo Bay	Syônai Province.
Oncinopus aranea DE HAAN	Tokyo Bay	Nagasaki.
Camposcia retusa LATREILLE	Tokyo Bay	Nagasaki.
Ophthalmias cervicornis (HERBST)	Kii Peninsula.	
Criocarcinus superciliosus (HERBST)	Yaku-zima.	
Menaethius monoceros LATREILLE	Tokyo Bay	Toyama Bay.
Huenia proteus DE HAAN	Tokyo Bay	Nagasaki.
Naxioides hirta A. M. EDWARDS	Kii Peninsula.	
Tylocarcinus styx (HERBST)	Tosa Bay.	
Doclea ovis (HERBST)	Kii Peninsula.	
Perinea tumida DANA	Northern Daitô-zima.	
Schizophrys aspera (H. M. EDWARDS)	Sagami Bay	Nagasaki.
Acanthophrys aculeatus (H. M. EDWARDS)	Sagami Bay.	
Micippa thalia (HERBST)	Tokyo Bay	Nagasaki.

Micippa philyra (HERBST) ..... Tokyo Bay ..... Toyama Bay.
M. platipes RÜPPELL ..... Izu Peninsula ..... Nagasaki.
Tiarinia cornigera LATREILLE ..... Iwate-ken ..... Nagasaki.
Lambrus (Rhinolambrus) pelagicus RÜPPELL ..... Kagosima Bay ..... Saisyûto.
Parthenope horrida FABRICIUS ..... Kagosima Bay.
Eumedonus pentagonus (RATHBUN) ..... Izu Peninsula.

BRACHYRHYNCHA

Catoptrus nitidus A. M. EDWARDS ..... Izu Peninsula.
Lybistes nitidus A. M. EDWARDS ..... Formosa.
Carupa laeviuscula HELLER ..... Tokyo Bay ..... Nagasaki.
Lissocarcinus orbicularis DANA ..... Sagami Bay.
L. laevis MIERS ..... Izu Peninsula ..... Nagasaki.
Scylla serrata (FORSKÅL) ..... Sagami Bay.
Neptunus (Neptunus) sanguinolentus (HERBST) ..... Tokyo Bay ..... Syônai Province.
N. (N.) pelagicus LINNAEUS ..... Sagami Bay ..... Nagasaki.
N. (Amphitrite) argentatus WHITE ..... Tokyo Bay.
N. (Hellenus) longispinosus DANA ..... Izu Peninsula.
N. (Achelous) granulatus (H. M. EDWARDS) ..... Izu Peninsula ..... Nagasaki.
Charybdis annulata (FABRICIUS) ..... Formosa.
Ch. orientalis DANA ..... Kii Peninsula.
Ch. erythrodactyla LAMARCK ..... Northern Daitô-zima.
Thalamita crenata LATREILLE ..... Kagosima ..... Nagasaki.
Th. danae STIMPSON ..... Kii Peninsula.
Th. prymna (HERBST) ..... Tokyo Bay ..... Nagasaki.
Th. stimpsoni A. M. EDWARDS ..... Kagosima Bay.
Th. picta STIMPSON ..... Sagami Bay ..... Nagasaki.
Th. sima H. M. EDWARDS ..... Tokyo Bay ..... Syônai Province.
Th. integra DANA ..... Bonin Islands.
Th. admete (HERBST) ..... Miyazaki-ken.
Podophthalmus vigil (FABRICIUS) ..... Kii Peninsula.
Kraussia integra (DE HAAN) ..... Tokyo Bay ..... Syônai Province.
K. rugulosa KRAUSS ..... Kagosima Bay.
Carpilius maculatus (LINNAEUS) ..... Kagosima Bay.
C. convexus (FORSKÅL) ..... Sagami Bay.
Atergatis floridus (LINNAEUS) ..... Tokyo Bay ..... Nagasaki.
Zozymus aenaeus (LINNAEUS) ..... Loo Choo.
Hypocolpus granulatus (DE HAAN) ..... Tokyo Bay.
(=*H. haani* RATHBUN.)
Cycloxanthops lineatus (A. M. EDWARDS) ..... Kii Peninsula ..... Nagasaki.
Platypodia granulosa (RÜPPELL) ..... Loo Choo.
Euxanthus exsculptus (HERBST) ..... Kagosima Bay.
Lophozozymus pictor (FABRICIUS) ..... ??
L. pulchellus A. M. EDWARDS ..... Amami Ôsima.
Daira perlata (HERBST) ..... Kagosima Bay.

Xantho (*Leptodius*) *exaratus* (H. M. Edwards) ..... Tokyo Bay ..... Nagasaki.
X. (*L.*) *cavipes* (Dana) ..... Miyazaki-ken.
X. (*L.*) *sanguineus* (H. M. Edwards) . Miyazaki-ken.
X. (*L.*) *gracilis* (Dana) ..... Kii Peninsula.
Xanthias lamarckii (H. M. Edwards) .. Kii Peninsula.
X. latifrons (de Man) ..... Tosa Bay.
Paraxanthias notatus (Dana) ..... Tosa Bay.
Carpilodes venosus (H. M. Edwards) .. Tokyo Bay ..... Syônai Province.
C. ruber A. M. Edwards ..... Bonin Islands.
C. cinctimanus (White) ..... Sagami Bay.
C. monticulosus A. M. Edwards ..... Tosa Bay.
C. stimpsoni A. M. Edwards ..... Loo Choo.
C. margaritatus A. M. Edwards ..... Tosa Bay.
C. bellus (Dana) ..... Bonin Islands.
C. rugatus (H. M. Edwards) ..... Tosa Bay.
Neoliomera insularis (Adams & White) Tokyo Bay
Lachnopodus subacutus (Stimpson) .... Loo Choo.
Actaea savignyi (H. M. Edwards) .... Tokyo Bay ..... Toyama Bay.
A. calculosa (H. M. Edwards) ..... Nagasaki.
A. tomentosa (H. M. Edwards) ..... Kagosima.
A. hirsutissima (Rüppell) ..... Bonin Islands.
A. rufopunctata (H. M. Edwards) ... Tokyo Bay.
A. speciosa (Dana) ..... Northern Daitô-zima.
A. tumulosa Odhner ..... Northern Daitô-zima.
A. remota Rathbun ..... Tosa Bay.
A. rüppellii Krauss ..... Sagami Bay ..... Nagasaki.
A. cavipes (Dana) ..... Kagosima Bay.
Etisus laevimanus Randall ..... Tokyo Bay.
E. (*Etisodes*) *electra* (Herbst) ..... Loo Choo.
E. (*E.*) *splendidus* (Rathbun) ..... Northern Daitô-zima.
E. (*E.*) *dentatus* (Herbst) ..... Kagosima Bay.
Chlorodopsis areolata (H. M. Edwards) . Amami Ôsima.
Ch. pilumnoides (White) ..... Loo Choo.
Ch. nigrochrinita (Stimpson) ..... Izu Peninsula.
Ch. pugil (Dana) ..... Amami Ôsima.
Cymo melanodactylus de Haan ..... Kii Peninsula.
C. andreossyi (Audouin) ..... Loo Choo.
Chlorodiella nigra (Forskål) ..... Loo Choo.
Ch. laevissima (Dana) ..... Izu Peninsula.
Phymodius ungulatus (H. M. Edwards) . Loo Choo.
Ph. ornatus (Dana) ..... Loo Choo.
Sphaerozius nitidus Stimpson ..... Sendai Bay ..... Toyama Bay.
Pseudozius caystrus (Adams & White) . Bonin Islands.
Globopilumnus globosus (Dana) ..... Kôbe.
Ozius rugulosus Stimpson ..... Kagosima Bay.
Epixanthus frontalis (H. M. Edwards) . Sagami Bay.

E. dentatus (WHITE) ..... Formosa.
Lydia annulipes (H. M. EDWARDS) ..... Loo Choo.
Baptozius vinosus (H. M. EDWARDS) ..... Loo Choo.
Eriphia laevimana (LATREILLE) ..... Loo Choo.
E. l. smithii MCLEAY ..... Izu Peninsula ..... Nagasaki.
E. scabricula DANA ..... Loo Choo.
Dacryopilumnus rathbunae BALSS ..... Loo Choo.
Actumnus setifer DE HAAN ..... Tokyo Bay ..... Nagasaki.
Pilumnus vespertilio FABRICIUS ..... Izu Peninsula ..... Nagasaki.
P. scabriusculus ADAMS & WHITE ..... Izu Peninsula.
P. longicornis HILGENDORF ..... Izu Peninsula.
P. cursor A. M. EDWARDS ..... Northern Daitô-zima.
Domoecia hispida EUDOUX & SOULEYET ..... Loo Choo.
Trapezia cymodoce (HERBST) ..... Kii Peninsula.
T. c. guttata RÜPPELL ..... Amami Ôsima.
T. digitalis LATREILLE ..... Tosa Bay.
Tetralia glaberrima (HERBST) ..... Tosa Bay.
Ocypoda cordimana DESMAREST ..... Miyazaki-ken.
O. kuhli DE HAAN ..... ??
O. ceratophthalma (PALLAS) ..... Kii Peninsula.
Gelasimus annulipes H. M. EDWARDS ..... Loo Choo.
G. marionis nitidus (DANA) ..... Nagasaki.
G. lacteus DE HAAN ..... Ise Bay ..... Nagasaki.
Macrophthalmus telescopicus (OWEN) ..... Izu Peninsula ..... Nagasaki.
M. convexus STIMPSON ..... Sagami Bay.
M. latreillei (DESMAREST) ..... Tokyo Bay ..... Toyama Bay.
Euplax boscii (AUDOUIN) ..... Formosa.
Mictyris longicarpus LATREILLE ..... Loo Choo.
Grapsus grapsus tenuicrustatus (HERBST) ..... Amami Ôsima.
G. strigosus (HERBST) ..... Kagosima Bay.
Geograpsus grayi (H. M. EDWARDS) ..... Northern Daitô-zima.
G. crinipes (DANA) ..... Northern Daitô-zima.
Metopograpsus messor (FORSKÅL) ..... Bonin Islands (??Aomori Bay).
Pachygrapsus minutus A. M. EDWARDS ..... Kii Peninsula.
P. plicatus (H. M. EDWARDS) ..... Loo Choo.
Pseudograpsus albus STIMPSON ..... Kikai-sima (Loo Choo).
Sesarma (Sesarma) rotundata HESS ..... Formosa.
S. (S.) impressa H. M. EDWARDS ..... Formosa.
Helice leachii HESS ..... Sagami Bay.
Plagusia depressa tuberculata LAMARCK ..... Sagami Bay ..... Nagasaki.
Percnon planissimum (HERBST) ..... Tokyo Bay ..... Nagasaki.
Cardisoma hirtipes DANA ..... Loo Choo.
C. carnifex FABRICIUS ..... Loo Choo.
Gecarcoidea lalandii H. M. EDWARDS ..... Formosa.

The most northwardly distributed species of this group are *Tiarinia cornigera* and *Sphaerozius nitidus* (littoral inhabitants!)—

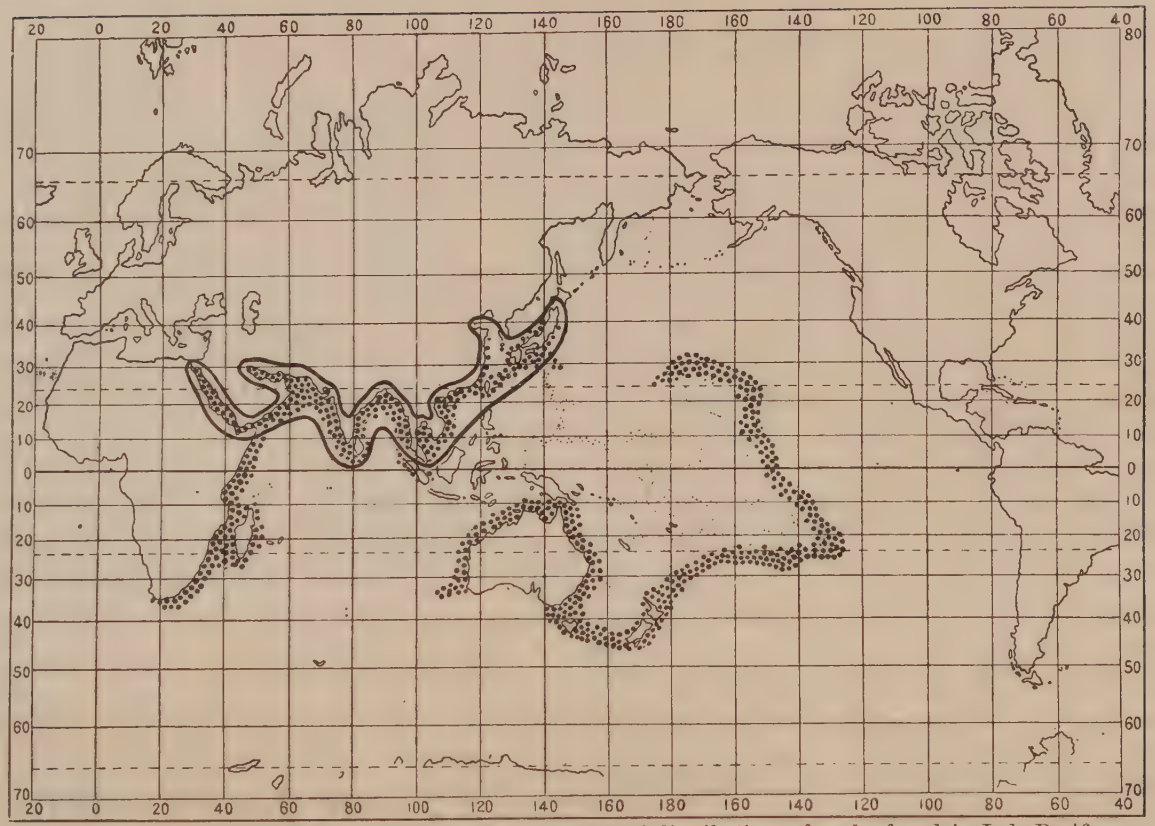
the former is found on the coast of Iwate-ken, the latter in Sendai Bay; also *Mursia armata curtispina* and *Lyreidus tridentatus* (inhabitants of the continental shelf) have been recorded from off Inuboe-zaki. No other species of this group seems to be propagated northward beyond Tokyo Bay. The species having their northern limit of distribution in Tokyo Bay and Sagami Bay amount to a vast number, about 46 in all, of which 19 are littoral inhabitants and the remainder are those of deeper bottom. Izu Peninsula appears to be nearly of the same nature regarding the tropical species, those having the northern limit of distribution at this locality number about 15, of which 6 are found in the littoral and the others in shallow water or on rather deeper bottom. In Kii Peninsula, such species are 16, of which 8 are littoral and the others belong to deeper bottom; 10 in Tosa Bay, all belong to the litoral fauna; 14 in Kagosima Bay, of which only 1 or 2 are found on deeper bottom; in Amami Ôsima there are 6 and in Loo Choo there are 22; in Northern Daitô-zima there are 8, in the Bonin Islands there are 6, and finally in Formosa, there are 7, all being littoral.

Some of these species are discontinuous in range between the southern localities and their northern limit, but it is clear that these species have been propagated toward Japan by the influence of the Kurosiwo, so that the more southern localities have the probability of containing these species, unless the condition of the habitat is especially unfavorable for them.

The number of species showing their northern limit of distribution at various localities on the Pacific side of Japan are as follows:

Coast of Iwate-ken	1	Tosa Bay	10
Sendai Bay	1	Miyazaki-ken	4
Inuboe-zaki	2	Kagosima Bay	14
Tokyo Bay	28	Amami Ôsima	6
Sagami Bay	18	Loo Choo	22
Izu Peninsula	15	Northern Daitô-zima	8
Ise Bay	1	Bonin Islands	6
Kii Peninsula	16	Formosa	7

From the above list, it may be concluded that the species from deeper waters of the genuine Indo-Pacific range farther northward than the littoral ones. *Sphaerozius nitidus* (usually littoral inhabitant!) ranges, as mentioned above, northward to Sendai Bay, but in this locality, its habitat, according to Dr. T. Imai of Onagawa, is deeper than in the native habitat in southern districts, although



Text-fig. 1. Sketch map showing the general boundary of distribution of crabs found in Indo-Pacific:

::::::: genuine Indo-Pacific species;

—— species restricted to the northern coasts of Indian Ocean, Malay Peninsula, and to the Far East.

Tiarinia cornigera, a pure littoral form, was obtained from the shore line of Iwate-ken by Mr. G. Toba of The Iwate-ken Normal School.

The remarkable gap in the number of species between Tokyo Bay and Inuboe-zaki evidently explains the fact that the Kurosiwo no longer gives direct influence to the marine fauna, especially to such reptantile animals as crabs, while in localities south of Tokyo Bay, the influence seems to be uniform, no remarkable gap existing between different localities, and the increase of the number of species closely coordinates with the decrease of latitude from north to south.

On the continental side of Japan, the various species found on the Pacific side generally stop at Nagasaki or its adjacent localities, such being about 44 in all, while only 15 species penetrate into the Japan Sea, viz.

Mursia armata curtispina .....toward Isikawa-ken.

Matuta lunaris
Micippa philyra
Menaethius monoceros
Actaea savignyi
Sphaerozius nitidus
Macrophthalmus latreillei
.....toward Toyama Bay.

Myra fugax
Leucosia longifrons
Lyreidus tridentatus
Elamena truncata
Neptunus sanguinolentus
Thalamita sima
Kraussia integra
Carpilodes venosus
.....toward Syônai Province.

The species found along the coast of the Japan Sea are much fewer than those on the Pacific side as the above list shows, but they range generally more northward than on the Pacific side. Thus, Syônai Province, which is situated almost on the same latitude as Sendai Bay, produces more numerous species than the latter.

III. Distribution in Japanese waters of the species peculiar to the Indian Ocean

This group include the species in the tropical regions of the Indian Ocean, bounded by the south and east coasts of Africa, Red Sea, Gulf of Aden, Gulf of Persia, Arabian Sea, coasts of Indian Archipelago, Bay of Bengal, coast of Burma, Mergui Archipelago,

Greater Sunda and Lesser Sunda, north and west coasts of Australia, etc. From this extensive region, various species are propagated toward Malaysian Archipelago, Banda Sea, Celebes, Arafûra Sea and southward to the east coast of Australia and New Caledonia, where they are mixed with those from the Central Pacific, and finally northward and eastward to the south China Sea, Philippines, Formosa, Loo Choo and the Japanese mainland. The species coming from this Indian region to Japan may be roughly divided into two sections from their distributional phase, namely, those widely distributed in the extensive regions in the Indian Ocean, and those restricted mainly to the northern coasts of the Indian Ocean, Malay Peninsula, and to the Far East.

1. *On the species restricted mainly to the northern coast of the Indian Ocean, Malay Peninsula, and to the Far East.*

On the northern coasts of the Indian Ocean including the Red Sea, Gulf of Aden, Gulf of Persia, west and east coasts of India, Ceylon, Andaman Sea, Malay Peninsula, Gulf of Siam, Indo-China, Philippines, coasts of south and north China, Formosa, Loo Choo, and the Japanese mainland, many peculiar species are found. These are about 83 in number, referable to 55 genera as enumerated in the following list:

List of species peculiar to the northern coasts of the Indo-Pacific, showing their northern or eastern limit of distribution.

Species in systematic order.	(Pacific side)	(Continental side)
DROMIACEA		
Dromia dehaani Rathbun	Hakodate	Toyama Bay.
D. intermedia Laurie	Tokyo Bay.	
Sphaerodromia kendalii (Alcock & Anderson)	Izu Peninsula.	
Cryptodromia tuberculata Stimpson	Kii Peninsula.	
C. bullifera Alcock	Kii Peninsula.	
OXYSTOMATA		
Calappa japonica Ortmann	Sagami Bay	Nagasaki.
C. gallus capellonis Laurie	Kii Peninsula.	
C. pustulosa Alcock	Tosa Bay.	
Actaeomorpha morum Alcock	Sagami Bay.	
Arcania erinaceus (Fabricius)	Sagami Bay.	
A. heptacantha (de Haan)	Sagami Bay	Syônai Province.
A. quinquespinosa Alcock & Anderson	Sagami Bay.	
Pariphiculus coronatus (Alcock & Anderson)	Sagami Bay	Nagasaki.
P. agaricifera Ihle	Kii Peninsula.	

Randallia lanata Alcock .....Sagami Bay.
R. eburnea Alcock .....Sagami Bay .....Corea Strait.
Ixoides cornutus McGilchrist .....Sagami Bay.
Leucosia craniolaris (Herbst) .....Kôbe.
L. obtusifrons de Haan .....Tokyo Bay .....Toyama Bay.
L. rhomboidalis de Haan .....Kii Peninsula .....Nagasaki.
Pseudophilyra tridentata Miers .....Sagami Bay .....Nagasaki.
Philyra carinata Bell .....Tokyo Bay.
Ph. tuberculosa Stimpson .....Hong Kong.
Raninoides serratifrons Henderson ....Sagami Bay.

OXYRHYNCHA

Rhynchoplax coralicola Rathbun .....Mutu Bay.
Trigonoplax unguiformis (de Haan)...Mutu Bay .....Syônai Province.
Achaeus spinosus Miers .....Tokyo Bay .....Nagasaki.
A. suluensis (Rathbun) .....Sagami Bay.
Cyrtomaja horrida Rathbun .....Izu Peninsula.
Doclea canalifera Stimpson .....Kii Peninsula.
Maja spinigera de Haan .....Tokyo Bay .....Nagasaki.
M. miersii Walker .....Sagami Bay .....Saisyûto.
Micippa margaritifera Henderson ....Izu Peninsula.
Lambrus (*Aulacolambrus*) *diacanthus* de Haan .....Tokyo Bay .....Nagasaki.
Harrovia elegans de Man .....Tokyo Bay .....Nagasaki.

BRACHYRHYNCHA

Lissocarcinus arkati Kemp .....Tosa Bay.
Lupocyclus philippinensis Semper .....Sagami Bay.
Neptunus (*Hellenus*) *longispinosus bidens* Laurie .....Sagami Bay.
Charybdis rivers-andersoni Alcock ....Sagami Bay.
Ch. lucifer (Fabricius) .....Formosa.
Ch. miles de Haan .....Tokyo Bay .....Nagasaki.
Ch. variegata (Fabricius) .....Izu Peninsula .....Nagasaki.
Ch. obtusifrons Leene .....Northern Daitô-zima.
Ch. truncata (Fabricius) .....Tokyo Bay .....Nagasaki.
Thalamita exetastica Alcock .....Sagami Bay.
Th. poissoni Audouin & Savignyi ....Sagami Bay.
Podophthalmus nacreus Alock .....Kii Peninsula.
Halimede ochtodes (Herbst) .....Ise Bay.
Liagore rubromaculata de Haan .....Sagami Bay .....Nagasaki.
Atergatis latissimus frontalis (de Haan) .....Northern Daitô-zima.
Zozymus gemmula ceylonica Laurie ....Tosa Bay.
Xantho distinguendus de Haan .....Tokyo Bay .....Toyama Bay.
X. reynaudii H. M. Edwards .....Kii Peninsula .....Nagasaki.
X. r. cultripes (Alcock) .....Tosa Bay.
Neoliomera intermedia Odhner .....Sagami Bay.
Actea lata Borradaile .....Tosa Bay.

Etisus (*Etisodes*) *anaglyptus* (H. M. Edwards)	Izu Peninsula	Nagasaki.
Actumnus squamosus (de Haan)	Tokyo Bay	Nagasaki.
Pilumnus sodalis (Alcock)	Bonin Islands.	
Pilumnopeus indica (de Man)	Izu Peninsula.	
Calmania prima Laurie	Tokyo Bay	Simane-ken.
Geryon trispinosus (Herbst)	Sagami Bay.	
Psopheticus hughi Rathbun	Tosa Bay.	
Goneplax renoculis Rathbun	Inuboe-zaki	Simane-ken.
Typhlocarcinops canaliculata Rathbun	Izu Peninsula.	
T. ocularia Rathbun		Simane-ken.
Mertonia lanka Laurie	Sagami Bay	
Thaumastoplax orientalis Rathbun	Kii Peninsula	Nagasaki.
Parathelphusa germaini Rathbun		Nagasaki.
P. sinensis H. M. Edwards	Formosa.	
Potamon (*Geothelphusa*) *obtusipes* Stimpson	Amami Ôsima.	
Pinnotheres parvulus Stimpson	Tokyo Bay	Nagasaki.
P. cardii Bürger	Tokyo Bay	Syônai Province.
Macrophthalmus japonicus de Haan	Aomori Bay	Corea, west side.
Camptandrium sexdentatum Stimpson		Nagasaki.
Leipocten sordidulum Kemp	Formosa.	
Scopimera globosa de Haan	Usu Bay	Nagasaki.
Tmethypocoelis ceratophora Koelbel	Formosa.	
Sesarma (*Sesarma*) *picta* (de Haan)	Sagami Bay	Toyama Bay.
S. (*S.*) *intermedia* (de Haan)	Tokyo Bay	Isikawa-ken.
S. (*S.*) *bocourti* A. M. Edwards	Tokyo Bay??	
Sarmatium punctatum (A. M. Edwards)	Kagosima Bay.	
Clistocoeloma merguiense de Man	Ise Bay.	

Of these the most extensively distributed species are *Dromia dehaani* (Gulf of Aden to Hakodate), *Trigonoplax unguiformis* (India to Mutu Bay), *Scopimera globosa* (Ceylon to Usu Bay, Hokkaidô); they are the representatives of those which have the northernmost limit of distribution in the Japanese waters.

Amongst the littoral forms, *Rhynchoplax* is restriteed to the coasts of Japan and China, though one species, *R. coralicola* Rathbun ranges from Mutu Bay south to Ceylon. *Neorhynchoplax* (Sakai 1938) on the other hand, is largely restricted to the coasts of India, though one species, *Neorhynchoplax sinensis* (Shen) is endemic to North China. The genus *Asthenognathus*, probably to be included in this group, is represented by two species, one, *A. hexagonum* Rathbun, occurring on the coast of Siam and the other, *A. inaequipes* in Japanese seas (Hakodate, Mutu Bay, Sendai Bay, Inland Sea, Osaka Bay). The

species of the family Ocypodidae are usually purely tropical, but to our interest, *Scopimera globosa* DE HAAN was obtained from the coast of Usu Bay, Hokkaidô. The westernmost range of the species is Ceylon, while its subspecies and other related species have been recorded from Formosa, China or other southern tropical localities.

The number of species of this group showing their northern limit of distribution at each locality on the Pacific side of Japan are as follows:

Usu Bay	1	Kii Peninsula	10
Hakodate	1	Tosa Bay	6
Mutu Bay	3	Kagosima	1
Inuboe-zaki	1	Amami Ôsima	1
Tokyo Bay	16	Bonin Islands	1
Sagami Bay	22	Northern Daitô-zima	2
Izu Peninsula	7	Formosa	4
Ise Bay	2		

On the Japan Sea side, Nagasaki possesses about 35 species of this group, while only 11 species penetrate into Japan Sea, viz.

Calmania prima
Typhlocarcinops ocularia } ..... toward Simane-ken.
Goneplax renoculis
Sesarma intermedia ..... toward Isikawa-ken.
Leucosia obtusifrons
Dromia dehaani
Xantho distinguendus } ..... toward Toyama Bay.
Sesarma picta
Arcania heptacantha
Trigonoplax unguiformis } ..... toward Syônai Province.
Pinnotheres cardii

Of these species, *Xantho distinguendus, Sesarma picta, Pinnotheres cardii* are found on the east coast of Corea also (Yellow Sea side), as well as on the coast of North China.

2. *On the species inhabiting the extensive regions in the Indian Ocean.*

Among the vast number of species found in this extensive region, those propagated toward Japan are about 104 in all, referable to 72 genera, as enumerated in the following list:

List of species from the Indian Ocean, showing their northern limit of distribution in Japan.

Species in systematic order.	(Pacific side)	(Continental side)
DROMIACEA		
Dromidiopsis cranioides (DE MAN)	Sagami Bay.	
Cryptodromia tumida typica STIMPSON	Sagami Bay.	
Conchoecetes artificiosus (FABRICIUS)	Sagami Bay	Nagasaki.
Homola orientalis HENDERSON	Sagami Bay.	
Latreillia valida DE HAAN	Mutu Bay	Syônai Province.
Latreillopsis bispinosa HENDERSON	Sagami Bay	Nagasaki.
OXYSTOMATA		
Tymolus uncifer (ORTMANN)	Iwate-ken	Toyama Bay.
Dorippe dorsipes (LINNAEUS)	Tokyo Bay	Toyama Bay.
Ethusa sexdentata (STIMPSON)	Inuboe-zaki	Toyama Bay.
E. latidactyla (PARISI)	Sagami Bay.	
Calappa bicornis MIERS	Kii Peninsula.	
C. lophos (HERBST)	Tokyo Bay	Nagasaki.
Matuta planipes FABRICIUS	Ise Bay	Syônai Province.
Oreophorus (*Oreophorus*) *ornatus* IHLE	Sagami Bay.	
Nursia plicata (HERBST)	Osaka Bay.	
Arcania undecimspinosa DE HAAN	Iwate-ken	Syônai Province.
Myra fugax coalita HILGENDORF	Tokyo Bay.	
Leucosia unidentata DE HAAN	Tokyo Bay	Nagasaki.
L. haematosticta ADAMS & WHITE	Sagami Bay	Nagasaki.
L. rhomboidalis DE HAAN	Kii Peninsula	Nagasaki.
Philyra platycheira DE HAAN	Izu Peninsula	Toyama Bay.
Cosmonotus grayii ADAMS & WHITE	Sagami Bay	Simane-ken.
Notopus dorsipes (FABRICIUS)	Sagami Bay	Nagasaki.
OXYRHYNCHA		
Paratymolus pubescens MIERS	Tokyo Bay	Toyama Bay.
P. sexspinosus MIERS	Izu Peninsula.	
Pleistacantha moseleyi MIERS	Inuboe-zaki	Nagasaki.
Simocarcinus camelus pinnirostris KLUNZINGER	Tosa Bay.	
Naxioides hystrix (MIERS)	Tokyo Bay	Yamaguti-ken.
Rochinia veltina (MIERS)	Izu Peninsula.	
R. pulchra (MIERS)	Kii Peninsula.	
Hyastenus diacanthus (DE HAAN)	Tokyo Bay	Nagasaki.
H. borradailei RATHBUN	Sagami Bay.	
H. elongatus ORTMANN	Tokyo Bay	Nagasaki.
Sphaenocarcinus stimpsoni (MIERS)	Sagami Bay.	
Hoplohrys oatesii HENDERSON	Amakusa.	
Acanthophrys longispinus (DE HAAN)	Tokyo Bay.	
A. spinosus (MIERS)	Sagami Bay.	
Lambrus (*Lambrus*) *longimanus* LEACH	Formosa.	

L. (*Platylambrus*) *validus* DE HAAN..Tokyo Bay .....Syônai Province.
L. (*P.*) *echinatus* (HERBST) .....Formosa.
L. (*Rhinolambrus*) *contralius* HERBST. Sagami Bay.
L. (*R.*) *longispinis* MIERS .....Sagami Bay .....Nagasaki.
L. (*Pseudolambrus*) *harpax* ADAMS & WHITE .....Sagami Bay.
L. (*Ps.*) *beaumontii* ALCOCK .....Sagami Bay.
Oethra scruposa (LINNAEUS) .....Kii Peninsula.
Cryptopodia fornicata FABRICIUS .....Sagami Bay.
Zebrida adamsii WHITE .....Kagosima Bay.
Eumedonus granulosus MCGILCHRIST ..Izu Peninsula.
E. zebra ALCOCK .....East China Sea.

BRACHYRHYNCHA

Gomeza bicornis GRAY .....Sagami Bay .....Isikawa-ken.
Ovalipes iridescens (MIERS) .....Tosa Bay.
Lissocarcinus polybioides ADAMS & WHITE .....Sagami Bay .....Nagasaki.
Lupocyclus rotundata ADAMS & WHITE. Sagami Bay .....Nagasaki.
Neptunus (*Amphitrite*) *tenuipes* DE HAAN .....Nagasaki.
N. (*A.*) *gladiator* (FABRICIUS) .....Tokyo Bay .....Syônai Province.
N. (*Hellenus*) *hastatoides* (FABRICIUS). Tokyo Bay .....Toyama Bay.
N. (*Achelous*) *orbitospinis* (RATHBUN). Izu Peninsula.
Charybdis cruciata (HERBST) .....Sagami Bay .....Nagasaki.
Ch. anisodon DE HAAN .....Formosa.
Ch. natator HERBST .....Kii Peninsula.
Ch. bimaculata (MIERS) .....Sendai Bay .....Syônai Province.
Thalamita oculea ALCOCK .....Sagami Bay.
Kraussia nitida STIMPSON .....Izu Peninsula .....Nagasaki.
Atergatis integerrimus (LAMARCK) ....Tokyo Bay.
A. dilatatus DE HAAN .....China Sea.
Medaeus granulosus (HASWELL) .....Tokyo Bay .....Syônai Province.
Micropanope tuberculidens RATHBUN ...Tosa Bay.
Carpilodes coelatus ODHNER .....Bonin Islands.
C. erythrus (LANCHESTER) .....Izu Peninsula .....Nagasaki.
Atergatopsis signatus (ADAMS & WHITE) .....Northern Daitô-zima.
Actaea pulchella A. M. EDWARDS .....Izu Peninsula.
A. depressa (WHITE) .....Sagami Bay.
A. helleri A. M. EDWARDS .....Bonin Islands.
A. polyacantha (HELLER) .....Izu Peninsula.
A. perspinosa BORRADAILE .....Bonin Islands.
A. (*Banareia*) *kraussi* HELLER .....Sagami Bay.
Calvactaea tumida WARD .....Sagami Bay.
Galene bispinosa (HERBST) ..... ??
Ozius tuberculosus H. M. EDWARDS ....Northern Daitô-zima.
Epixanthus corrosus A. M. EDWARDS ..Sagami Bay.

Heteropilumnus quadrispinosus (Zehntner) ..... Loo Choo.
Heteropanope glabra Stimpson ..... Tosa Bay.
Glabropilumnus dispar (Dana) ..... Loo Choo.
Trapezia cymodoce areolata Dana..... Kii Peninsula.
Carcinoplax vestitus (de Haan) ..... Iwate-ken ..... Syônai Province.
C. longimanus (de Haan) ..... Hakodate ..... Syônai Province.
Eucrate crenata de Haan ..... Tokyo Bay ..... Syônai Province.
Homoioplax haswelli (Miers) ..... Inuboe-zaki ..... Nagasaki.
Ceratoplax ciliata Stimpson ..... Kii Peninsula.
Typhlocarcinodes hirsutus (Borradaile) ..... Sagami Bay ..... Yamaguti-ken.
Camatopsis rubida Alcock & Anderson. Sagami Bay ..... Hukui-ken.
Hexapus sexpes (Fabricius) ..... Kii Peninsula.
Potamon (Oziothelphusa) bouvieri Rathbun ..... Nagasaki.
Cymopolia serripes Alcock & Anderson ..... Sagami Bay.
Gelasimus arcuatus de Haan ..... Kii Peninsula ..... Nagasaki.
Macrophthalmus tomentosus (Souleyet) ..... Formosa.
Ilyoplax integra (Tesch) ..... Formosa.
Geograpsus lividus stormi de Man .... Northern Daitô-zima.
Varuna litterata (Fabricius) ..... Sagami Bay ..... Nagasaki.
Brachynotus harpax Hilgendorf ..... Formosa.
Cyclograpsus intermedius Ortmann .... Sagami Bay ..... Saisyûto.
Sesarma (Sesarma) smithii H. M. Edwards ..... Loo Choo.
S. (Chiromantes) bidens (de Haan).. Izu Peninsula ..... Nagasaki.
S. (Parasesarma) plicata Latreille) ..... Nagasaki.

Of these species, about 47 range northward toward Tokyo Bay and Sagami Bay; most of these are the inhabitants on a rather deep bottom or on the continental shelf, those regarded as the littoral or land species being only 5 in all, viz., *Cryptodromia tumida*, *Elamena truncata*, *Medaeus granulosus*, *Cyclograpsus intermedius*, *Sesarma bidens*.

On the other hand, those ranging northward beyond Tokyo Bay are *Homoioplax haswelli*, *Ethusa sexdentata*, and *Pleistacantha moseleyi* (all being rather deep-water forms), which are obtained from off Inuboe-zaki, while six other species range farther northward, viz. *Charybdis bimaculata* and *Tymolus uncifer* are obtained from Sendai Bay, *Arcania undecimspinosa* and *Carcinoplax vestitus* from the coast of Iwate, *Latreillia valida* from Mutu Bay, and *Carcinoplax longimanus* (a rather deep-water form) from Hakodate Bay.

Of the other species belonging to this group, about 10, of which two are littoral and the others rather deep forms, range to Izu Peninsula; 11, of which only three are littoral, to Kii Peninsula; 4, of which one is littoral, to Tosa Bay; only 2 (all littoral) to Kagosima, while in Loo Choo, Northern Daitô-zima, Bonin Islands, and Formosa such species are about 15, and they are all inhabitants of the shallow waters on coral reefs.

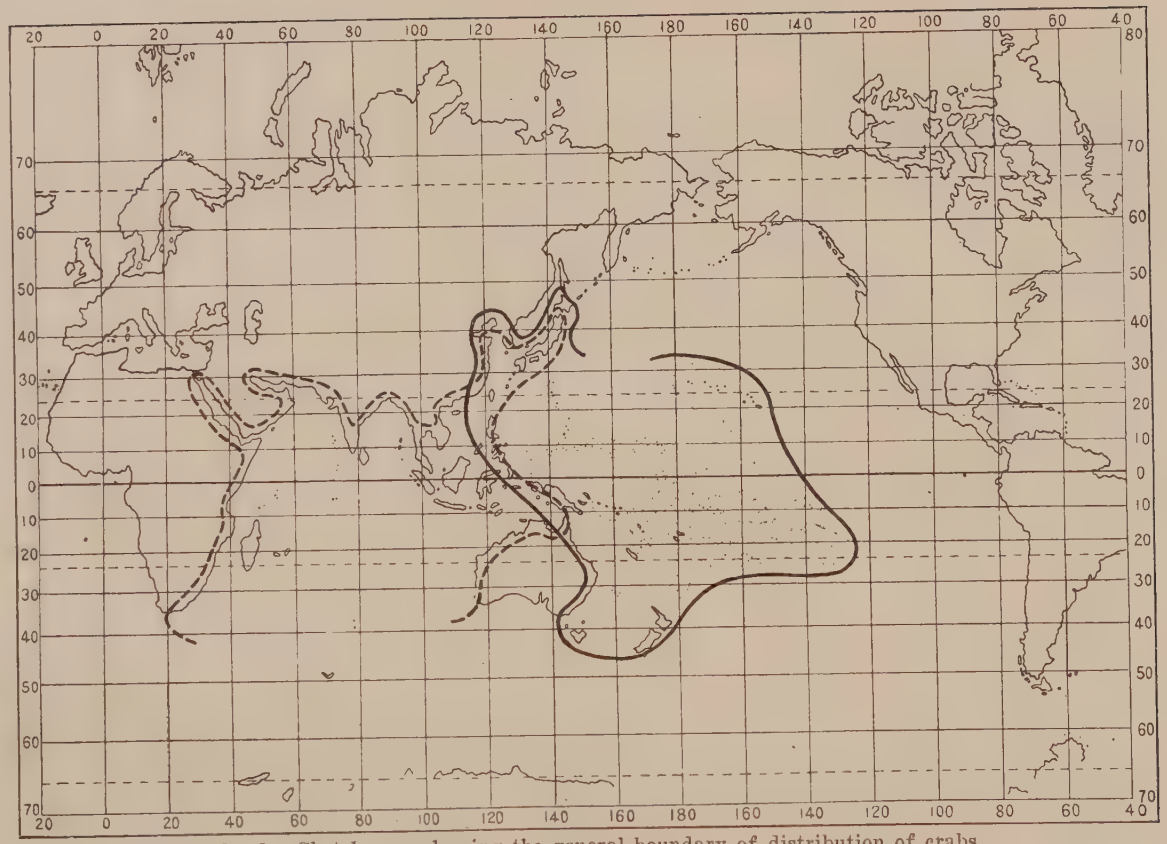
The land crabs—Ocypodidae and Grapsidae—are largely restricted to Formosa, but the following four species range unusually farther northward, viz., *Gelasimus arcuatus* (Kii Peninsula), *Gelasimus lacteus* (Ise Bay), *Cyclograpsus intermedia* and *Sesarma* (*Chiromantes*) *bidens* (Sagami Bay).

The number of species in each locality on the Pacific side of Japan, according to their northern limit of distribution are as follows:

Hakodate	1	Ise Bay	1
Mutu Bay	1	Kii Peninsula	11
Iwate-ken	2	Tosa Bay	4
Sendai Bay	2	Kagosima	2
Inuboe-zaki	3	Loo Choo	3
Tokyo Bay	15	Northern Daitô-zima	3
Sagami Bay	32	Bonin Islands	3
Izu Peninsula	10	Formosa	6

On the Japan Sea side, Nagasaki has about 37 species of this group as seen in the list given on pp. 40–42, while the following species penetrate into the Japan Sea, viz.

Naxioides hystrix, *Typhlocarcinodes hirsutus* ..... toward Yamaguti-ken.
Cosmonotus grayi ..... toward Simane-ken.
Gomeza bicornis ..... toward Isikawa-ken.
Tymolus uncifer, *Dorippe dorsipes*, *Ethusa sexdentata*, *Philyra platycheira*, *Paratymolus pubescens*, *Neptunus* (*Hellenus*) *hastatoides* ..... toward Toyama Bay.
Latreillia valida, *Matuta planipes*, *Arcania undecimspinosa*, *Lambrus validus*, *Neptunus* (*Amphitrite*) *gladiator*



Text-fig. 2. Sketch map showing the general boundary of distribution of crabs found in the Indian and Pacific Ocean:

---- Indian species; —— tropical Pacific species.

Charybdis bimaculata
Medaeus granulosus
Carcinoplax longimanus
C. vestitus
Eucrate crenata
} ..... toward Syônai Province.

On the Yellow Sea side of Corea, *Hyastenus diacanthus* ranges toward Zinsen, while *Matuta planipes, Calappa lophos, Neptunus* (*Amphitrite*) *gladiator* range to only Saisyûto.

IV. Distribution in Japanese waters of the species inhabiting the tropical Pacific Ocean

The tropical regions of the western half of the Pacific Ocean, bounded by the Sandwich Islands, Polynesia, New Caledonia, west coast of Australia, New Guinea, Melanesia, Philippines, etc. form a peculiar fauna, represented by a vast number of purely tropical species, of which those ranging to the Japanese waters are about 71, referable to 55 genera. These regions comprise a large number of coral reefs and islands such as Hawaii, Paumotu, Marquesas, Society, Tahiti, Cook, Tonga, Samoa, Fiji, New Hebrides, Santa Cruz, Solomon, Gilbert, Bismark, Palao, Marshall, etc. These islands provide good habitats for the crabs occurring on the littoral as well as on the shallow bottom. Many species seem to have been propagated from these localities to Japan as well as to Malay Archipelago, Australia, and New Caledonia, where they are mixed with the true Indian species. These species are about 68, referable to 53 genera as enumerated in the following list:

List of species from the tropical Pacific Ocean showing their northern limit of distribution in Japan.

Species in systematic order.	(Pacific side)	(Continental side)
DROMIACEA		
Cryptodromia incisa HENDERSON	Suruga Bay.	
C. areolata IHLE	Sagami Bay	Nagasaki.
C. coronata STIMPSON	Bonin Islands.	
Petalomera lateralis (GRAY)	??Madsicasima.	
P. wilsoni (FULTON & GRANT)	Mutu Bay	Tugaru Strait.
P. japonica (HENDERSON)	Hakodate	Nagasaki.
Homolomannia sibogae IHLE	Sagami Bay.	
Homola (*Parhomola*) *japonica* PARISI.	Sagami Bay.	
OXYSTOMATA		
Ethusina abyssicola challengeri (MIERS)	off Bosyû.	

Calappa terrae-reginae WARD ..... Corea Strait.
Ebalia jordani RATHBUN ..... Suruga Bay.
E. tuberculosa A. M. EDWARDS ..... Mutu Bay ..... Toyama Bay.
Merocryptus lambriformis A. M. EDWARDS ..... Sagami Bay ..... Goto Isls.
Heteronucia venusta NOBILI ..... Izu Peninsula.
Cryptocnemus obolus ORTMANN ..... Sagami Bay.
Leucosia australiensis MIERS ..... Suruga Bay.
Philyra laminata DOFLEIN ..... Sagami Bay.
Raninoides personatus WHITE ..... Kii Peninsula.
Notopus ovalis HENDERSON ..... Izu Peninsula ..... Hukui-ken.

OXYRHYNCHA

Achaeus superciliaris (ORTMANN) ..... Sagami Bay.
Platymaja wyville-thomsoni MIERS ..... Tosa Bay ..... Nagasaki.
Picrocherus armatus A. M. EDWARDS ... Kii Peninsula.
Naxioides mammillata (ORTMANN) .... Kii Peninsula ..... Nagasaki.
Micippa cristata granulipes ZEHNTNER ..... Saisyûto.
Tiarinia tiarata (ADAMS & WHITE) ..... Tosa Bay.
T. angusta DANA ..... Loo Choo.
Xenocarcinus tuberculatus WHITE ..... Izu Peninsula.
Lambrus (Platylambrus) nummifera RATHBUN ..... Sagami Bay.
Tutankhamen pteromerus (ORTMANN) .. Inuboe-zaki ..... Toyama Bay.
Zalasius dromiaeformis (DE HAAN) .... Tokyo Bay ..... Nagasaki.

BRACHYRHYNCHA

Parathranites orientalis MIERS ..... Sagami Bay ..... Hukui-ken.
Neptunus (Neptunus) pubescens (DANA) ..... Izu Peninsula.
Charybdis japonica (A. M. EDWARDS) .. Tokyo Bay ..... Syônai Province.
Ch. amboinensis LEENE ..... Kii Peninsula.
Thalamita wakensis EDMONDSON ..... Tosa Bay.
Th. parvidens (RATHBUN) ..... Izu Peninsula.
Lophozozymus incisus (H. M. EDWARDS) . Ise Bay.
Xanthias tetraodon (HELLER) ..... Kagosima Bay.
X. canaliculatus RATHBUN ..... Tosa Bay.
Paraxanthias elegans (STIMPSON) ..... Izu Peninsula.
Carpilodes laevis A. M. EDWARDS ..... Loo Choo.
Actaea consobrina A. M. EDWARDS .... Bonin Islands.
Globopilumnus actumnoides A. M. EDWARDS ..... Northern Daitô-zima.
Acanthodes armatus DE HAAN ..... Sagami Bay ..... Saisyûto.
Dacryopilumnus eremita NOBILI ..... Northern Daitô-zima.
Pilumnus tomentosus LATREILLE ..... Tokyo Bay .....
P. minutus de HAAN ..... Aomori Bay ..... Nagasaki.
P. orbitospinis RATHBUN ..... Sagami Bay.
P. barbatus A. M. EDWARDS ..... Nagasaki.
Trapezia cymodoce dentata (MCLEAY) .. Loo Choo.

Ommatocarcinus macgillivrayi White ..Tokyo Bay .....Nagasaki.
Cymopolia oahuensis (Rathbun) .....Inuboe-zaki.
Manella spinipes (de Man) .....Izu Peninsula.
Gelasimus gaimardi H. M. Edwards ...Bonin Islands.
G. latreillei H. M. Edwards .....Loo Choo.
G. dubius Stimpson .....Loo Choo.
Macrophthalmus pacificus Dana .....Loo Choo.
Grapsus longitarsis Dana .....Kagosima.
Metopograpsus thukuhar (Owen) .....Bonin Islands.
Pachygrapsus fakaravensis Rathbun ..Northern Daitô-zima.
Ptychognathus barbatus
A. M. Edwards .....Loo Choo.
P. glaber Stimpson .....Bonin Islands.
Pseudograpsus crassus A. M. Edwards.. ??
Hemigrapsus sanguineus (de Haan)....Akkesi Bay .....Kaiba Is.
Sesarma (Parasesarma) erythrodactyla
Hess .....Tosa Bay.
Cyclograpsus longipes Stimpson .....Bonin Islands.
Metasesarma aubryi A. M. Edwards...Formosa.
Plagusia dentipes de Haan .....Iwate-ken .....Nagasaki.

The crabs of the families Ocypodidae and Grapsidae are all littoral or land-inhabitants, and do not range beyond Loo Choo, however, such littoral species as *Hemigrapsus sanguineus, Plagusia dentipes* range farther north, the former toward Akkesi Bay and south of Sakhalin, the latter toward the coast of Iwate-ken. *Pilumnus minutus,* a sub-littoral or deeper water form, also belongs to the most extensively distributed species, ranging from Australia, Malaysian Archipelago, Formosa, northward to Aomori Bay and farther to North China and Manchoukuo. As to the land crabs, about 17 species range to Formosa, Loo Choo, Northern Daitô-zima, and the Bonin Islands, and only a few species have been recorded from Kagosima, but none from localities beyond Kagosima.

The number of the species inhabiting the waters around the Japanese mainland decreases gradually as the latitude becomes higher, and a remarkable gap in number of species is noticeable only at the point between Tokyo Bay and Inuboe-zaki, exactly as in the genuine Indo-Pacific or pure Indian species.

The number of species in this group showing their northern limit of distribution at each locality on the Pacific side of Japan are as follows:

Akkesi Bay	1	Ise Bay	1
Hakodate	1	Kii Peninsula	4
Mutu Bay	3	Tosa Bay	5
Iwate-ken	1	Kagosima	2
Inuboe-zaki	2	Bonin Islands	6
Tokyo Bay	5	Loo Choo	7
Sagami Bay	11	Northern Daitô-zima	3
Izu Peninsula	10	Formosa	1

On the continental side, Nagasaki comprises about 15 species, while the following few species penetrate into the Japan Sea:

Notopus ovalis, *Parathranites orientalis* ..... toward Hukui-ken.
Tutankhamen pteromerus ..... toward Toyama Bay.
Charybdis japonica ..... toward Syônai Province.
Petalomera wilsoni ..... toward Tugaru Strait.
Hemigrapsus sanguineus ..... toward Kaiba Islands.

In Corea, *Charybdis japonica* and *Hemigrapsus sanguineus* are found on the Yellow Sea side and probably occur on the coast of the Japan Sea (and the coast of North China); *Pilumnus minutus* was recently obtained from Dairen, Manchoukuo by Mr. M. Matsuo of the Dairen 2nd Middle School; while *Acanthodes armatus* has been reported from Saisyûto by Mr. T. Kamita (of Keizyo).

Some agreement may be found in the crab fauna between Hawaii and Japan on the one hand and, New Caledonia or Australia and Japan on the other, since the same species have been recorded from these extremely remote localities without any record from the intermediate localities. Thus, *Homola* (*Parhomola*) *japonica*, *Ebalia jordani*, *Achaeus superciliaris*, *Lambrus* (*Platylambrus*) *nummifera*, *Neptunus* (*Neptunus*) *pubescens*, *Xanthias canaliculata*, *Charybdis japonica*, *Cymopolia oahuensis* are known from Hawaii and Japan only. *Cryptodromia incisa*, *Petalomera lateralis*, *Calappa terrae-reginae*, *Leucosia australiensis*, *Picrocerus armatus*, *Paraxanthias elegans*, *Acanthodes armatus*, *Pilumnus orbitospinis*, *Pilumnus barbatus*, *Ommatocarcinus macgillivrayi* are recorded only from Japan and Australia or New Caledonia or New Zealand, without continuity of distribution. Whether this is merely due to insufficiency of investigation in the intermediate localities or to their being relics of forms widely distributed in some earlier period, may only be settled by future investigations.

V. Distribution of the species inhabiting the waters in the Far East

The local species found in the Far East are also very rich in number. Most of these are endemic to Japan and occur in Formosa, Loo Choo, and in various localities of the Japanese mainland, though some are common to China, Manchoukuo, and Corea, while only a few are endemic to China or Manchoukuo.

Although it is rather unnatural to divide the crab fauna of the Far East into two groups, the endemic Japanese forms and those distributed in the extensive regions in the whole Far East, yet it is true that the former are much more numerous than those recorded from China or Manchoukuo only. The reason may be attributed to the complexity of the shore line, the favorable condition of the sea-bottom and also to the direct influence of Kurosiwo in the Japanese Islands as compared to the coasts of the adjacent continent. I shall treat accordingly the endemic Japanese species as a special group for the present, although some of the species may be found by future studies to be widely distributed to the entire regions in the Far East.

1. Species common to Japan, China, and Manchoukuo.

The species common to Japan, China, and Manchoukuo are about 61, referable to 39 genera, as represented in the following list:

Species in systematic order.	Southern- or westernmost localities.	Northernmost localities: (Pacific side)	(Continental side)
DROMIACEA			
Petalomera granulata STIMPSON	Hong Kong	Tokyo Bay.	
OXYSTOMATA			
Dorippe japonica VON SIEBOLD	North China	Hakodate	Isikawa-ken.
D. granulata DE HAAN	Formosa	Hakodate	Syônai Prov.
Mursia armata DE HAAN	Nagasaki	Sagami Bay.	
Orithyia sinica LINNAEUS	Yellow Sea coasts.		
Ebalia minor MIERS	??		
E. rhomboidalis MIERS	??		
Arcania globata STIMPSON	South China	Sagami Bay.	
Leucosia vittata STIMPSON	Hong Kong	Onomiti.	
Philyra heterograna ORTMANN	Kagosima	Tokyo Bay.	
Ph. tuberculosa STIMPSON	Hong Kong	Formosa.	
Ph. pisum DE HAAN	Formosa	Iwate-ken	Syônai Prov.
Lyreidus politus PARISI	Hong Hong	Sagami Bay	Syônai Prov.
OXYRHYNCHA			
Rhynchoplax setirostris			

STIMPSON	Hong Kong	Sagami Bay.	
Pugettia incisa DE HAAN	Amoy	Hakodate	Syônai Prov.
P. quadridens DE HAAN	Nagasaki	Hakodate	Syônai Prov.
Heterocrypta transitans ORTMANN	Nagasaki	Sagami Bay.	

BRACHYRHYNCHA

Neptunus trituberculatus MIERS	Formosa	Hakodate	Syônai Prov.
Charybdis acuta A. M. EDWARDS	Hong Kong	Tokyo Bay	Saisyûto.
Cancer gibbosulus DE HAAN	Nagasaki	Iwate-ken	Syônai Prov.
Atergatis reticulatus DE HAAN	Amoy	Tokyo Bay	Saisyûto.
Carpilodes lophopus boninensis ODHNER	East China Sea	Sagami Bay.	
Actaea rüppelli orientalis ODHNER	Hong Kong	Iwate-ken	Syônai Prov.
A. (Banareia) subglobosa STIMPSON	Hong Kong	Sagami Bay.	
Chlorodopsis granulata STIMPSON	Hong Kong	Izu Peninsula.	
Actumnus dorsipes DE HAAN	Hong Kong	Sagami Bay.	
Heteropilumnus ciliatus STIMPSON	North China	Izu Peninsula	Nagasaki.
Pilumnopeus makiana RATHBUN	Formosa	Kagosima	Nagasaki.
Potamon (Geothelphusa) dehaani WHITE	Formosa	Aomori-ken	entire coast.
Pinnotheres cyclinus SHEN	North China	Miyazaki-ken	Nagasaki.
P. sinensis SHEN	North China	Iwate-ken	Isikawa-ken.
P. gordoni SHEN	North China	Izu Peninsula	Hakata (Kyûsyû).
Pinnixa tumida STIMPSON	Peichihli Bay	Hakodate.	
P. penultipedalis STIMPSON	Hong Kong	Nagasaki.	
Pinnaxodes major ORTMANN	Kii Peninsula	Tokyo Bay	(Wladivostok).
Tritodynamia horvathi NOBILI	North China	Tokyo Bay.	
T. rathbuni SHEN	North China	Tokyo Bay.	
T. intermedia SHEN	North China	Tokyo Bay.	
Ocypoda stimpsoni ORTMANN	Formosa	Iwate-ken.	
Macrophthalmus dilatatus DE HAAN	Formosa	Tokyo Bay.	
Cleistostoma dilatatum DE HAAN	Ariake Bay	Corea, west side.	
Paracleistostoma cristatum DE MAN	Hong Kong	Aomori Bay.	
Scopimera globosa longidactyla SHEN	Formosa	North China.	
S. bitympana SHEN	Formosa	North China.	
Acmaeopleura balssi SHEN	North China	Izu Peninsula.	
Eriocheir japonicus DE HAAN	Hong Kong	Hokkaidô	Sakhalin.
E. sinensis H. M. EDWARDS	Shanghai	Corea, west side.	
E. rectus STIMPSON	Macao	Formosa.	

E. leptognathus RATHBUN	Shanghai		Corea, west side.
Hemigrapsus penicillatus (DE HAAN)	Formosa	Akkesi Bay	Kaiba Is.
H. longitarsis MIERS	North China	Mutu Bay	Toyama Bay.
Gaetice depressus DE HAAN	Formosa	Akkesi Bay	Syônai Prov.
Sesarma haematocheir DE HAAN	Formosa	Iwate-ken	Syônai Prov.
S. dehaani H. M. EDWARDS	Formosa	Tokyo Bay	Syônai Prov.
S. gordoni SHEN	Hong Kong	Izu Peninsula.	
Chasmagnathus convexus DE HAAN	Hong Kong	Tokyo Bay	Saisyûto.
Helice tridens tridens DE HAAN	Formosa	Mutu Bay	Isikawa-ken.
H. t. latimera PARISI	Formosa		China.
H. t. sheni SAKAI	Peichihli Bay		Manchoukuo.
H. t. wuana RATHBUN	Formosa	Kagosima	China.
H. t. tientsinensis RATHBUN	North China		Corea, west side.

Although these species are probably originated from the southern tropical forms already referred to, yet, in the aspect of their distribution, they have much wider range than the latter, the northwardly distributed species, found in the localities north of Tokyo Bay being more numerous than in the other groups (about 19 species in all—cf. above list).

The well-known *Orithyia sinica* is strictly restricted to the coasts of North China, Manchoukuo and the west coast of Corea. The land crabs—*Ocypoda stimpsoni, Gelasimus arcuatus, Sesarma picta, Sesarma dehaani, Sesarma gordoni* are common species in Japan (south of Tokyo Bay) as well as in China, while the freshwater crab, *Potamon* (*Geothelphusa*) *dehaani* is found everywhere in Japan from Aomori-ken (41°32′N—K. KOBA, 1933) to Loo Choo, Formosa, and also in North China. Of the four varieties of the estuarine crab, *Helice tridens* DE HAAN, *typica* ranges most extensively, from Aomori Bay to Formosa, Corea, and North China, *tientsinensis* ranges from North China, Manchoukuo to the Yellow Sea side of Corea; *wuana* ranges from south of Kyûsyû, Formosa, China, and Yellow Sea side of Corea, and finally, *sheni* (SAKAI, 1939) is restricted to North China and Manchoukuo. The well-known estuarine or freshwater crab, *Eriocheir japonicus* shows the widest distribution, from Amoy (southernmost limit) through Formosa, Loo Choo, Kyûsyû, Sikoku, Honsyû, Hokkaidô to South Sakhalin, and also from Saisyûto, south and east coast of Corea, probably to the River Amur; *E. rectus* has been recorded only

from Macao and Formosa (east coast); while *E. leptognathus* and *E. sinensis* show almost the same distribution, ranging from Shanghai through North China and Manchoukuo to the Yellow Sea side of Corea. Among the Pinnotherid crabs, the peculiar *Pinnixa tumida,* which is the commensal of *Paracaudina chilensis* var. *ransonnettii,* is known only from Hakodate, Mutu Bay and Peichihli Bay (North China).

As in the former groups, the continental side of Honsyû includes much fewer species than the Pacific side. Those found on the coast

Text-fig. 3. Sketch map of the Far East indicating the geographical names cited in this paper.

along the Japan Sea are only 18 in number (cf. above list), most of which are the same as those found on the coast north of Tokyo Bay and their distribution ranges from the Corea Strait toward Syônai Province or even toward South Sakhalin. The shore crab, *Hemigrapsus penicillatus,* which is a nearest kin of *H. sanguineus* ranging from Australia toward Sakhalin, also shows the widest distribution of the forms in this group, being found in the entire Japanese waters from Formosa to South Sakhalin, and also in North China and Corea.

The Yellow Sea side of Corea comprises a relatively small number of species, but these are composed of various elements. Besides the tropical species already referred to, *Dorippe granulata, Dorippe japonica, Neptunus trituberculatus, Ilyoplax pusillus, Cleistostoma dilatatum, Paracleistostoma cristatum, Hemigrapsus penicillatus, Sesarma haematocheir* and *Sesarma dehaani* are common in this locality as well as in Japan, Manchoukuo, and North China, while *Orithyia sinica, Eriocheir sinensis, Eriocheir leptognathus, Helice tientsinensis* are propagated, as already referred to, from North China and Manchoukuo, and lastly, *Pachygrapsus crassipes* is propagated from the northern cold regions. On the Japan Sea side of Corea, *Dorippe granulata, Hemigrapsus penicillatus, Eriocheir japonicus* are only the species of this group known.

2. *Endemic Japanese species.*

The purely endemic species known number about 176, referable to 107 genera; these are found mostly on the Pacific coast of Honsyû, Sikoku, and Kyûsyû. The fauna of Loo Choo, Bonin Islands, Northern Daitô-zima, Formosa is generally admitted as purely tropical, comprising only a small number of the species of this group as shown in the following list:

List of endemic Japanese species showing their northern and southern limit of distribution.

Species in systematic order.	Southern- or westernmost localities.	Northernmost localities. (Pacific side)	(Continental side)
DROMIACEA			
Dicranodromia döderleini Ortmann		Sagami Bay.	
Cryptodromia tumida bispinosa Sakai	Tosa Bay.		
C. t. trispinosa Sakai		Kii Peninsula.	

C. nipponensis YOKOYA ..... Goto Isls.
Petalomera angulata SAKAI ..... Izu Peninsula.
P. fukuii SAKAI ..... Izu Peninsula ... Tokyo Bay.
P. atypica SAKAI ..... Sagami Bay.
P. nodosa SAKAI ..... Tokyo Bay.
Dynomene tanensis YOKOYA .. Tane Is.
Homola (Parhomola) majora (KUBO) ..... Izu Peninsula ... Tokyo Bay.
Latreillia phalangium DE HAAN ..... Nagasaki ..... Tokyo Bay ..... Syônai Prov.
Latreillopsis laciniata SAKAI.. Kii Peninsula .. Izu Peninsula.

OXYSTOMATA

Tymolus japonicus STIMPSON.. Nagasaki ..... Hakodate ..... Syônai Prov.
Cymonomus granulata japonica BALSS ..... Sagami Bay.
Ethusa quadrata SAKAI ..... Sagami Bay.
E. izuensis SAKAI ..... Izu Peninsula ... Sagami Bay.
E. minuta SAKAI ..... Sagami Bay.
Ebalia sikokuensis YOKOYA ... Tosa Bay.
E. longimana ORTMANN .... Nagasaki ..... Sagami Bay .... Toyama Bay.
E. bituberculata MIERS ..... Kagosima ..... Kii Peninsula.
E. conifera ORTMANN ..... Tokyo Bay.
E. tuberculata YOKOYA ..... Kagosima ..... Kii Peninsula.
Praebebalia longidactyla YOKOYA ..... Nagasaki ..... Ise Bay.
Oreophorus (Oreotlos) latusoides SAKAI ..... Nagasaki.
Nursia elegans japonica SAKAI. Kii Peninsula .. Sagami Bay.
Arcania undecimspinosa elongata YOKOYA ..... Tosa Bay ..... Sagami Bay.
A. orientalis MIERS ..... Kii Peninsula.
Cryptocnemus pentagonus ORTMANN ..... Nagasaki ..... Kagosima Bay.
Leucosia formosensis SAKAI .. Formosa.
Philyra syndactyla ORTMANN.. Nagasaki ..... Hakodate.
Ph. kanekoi SAKAI ..... Nagasaki ..... Sagami Bay.
Ph. nipponensis YOKOYA ..... Sagami Bay.
Lyreidus brevifrons SAKAI ... Tosa Bay.
Notopus misakiensis SAKAI ..... Sagami Bay.

OXYRHYNCHA

Halicarcinus orientalis SAKAI.. Ise Bay ..... Tokyo Bay.
Rhynchoplax messor STIMPSON ..... Izu Peninsula ... Mutu Bay ..... Toyama Bay.
Achaeus japonicus DE HAAN .. Nagasaki ..... Tokyo Bay.
A. robustus YOKOYA ..... Bungo Strait.
A. spinifrons SAKAI ..... Kii Peninsula .. Sagami Bay.
A. trituberculatus RATHBUN..... Tokyo Bay.
A. tuberculatus MIERS ..... Nagasaki ..... Aomori-ken ..... Toyama Bay.

A. brevidactylus Sakai ..... Izu Peninsula.
A. pugnax (de Man) ..... Nagasaki ..... Sagami Bay.
A. elongatus Sakai ..... Sagami Bay.
A. akanensis Sakai ..... Izu Peninsula.
Pseudocollodes demani Balss.. Bungo Strait ... Inuboe-zaki.
Achaeopsis rostrata Sakai ..... Sagami Bay.
Macrocheira kaempferi de Haan ..... Nagasaki ..... Tokyo Bay.
Oregonia mutsuensis Yokoya.. Sendai Bay .... Mutu Bay.
Pleistacantha simplex .. .... Rathbun ..... Nagasaki ..... Sagami Bay.
P. sancti-johannis Miers ... Nagasaki ..... Tokyo Bay.
P. nipponensis Yokoya ..... Bungo Strait ... Inuboe-zaki.
P. terribilis Rathbun ..... Ôse-zaki.
P. (Parapleisticantha) japonica Yokoya ..... Nagasaki ..... Izu Peninsula.
Cyrtomaja owstoni Terazaki.. Nagasaki ..... Tokyo Bay.
C. intermedia Sakai ..... Sagami Bay.
C. platypes Yokoya ..... Tane Is. ..... Kii Peninsula.
Zewa nipponica Sakai ..... Loo Choo ..... Tokyo Bay ..... Toyama Bay.
Z. okamotoi Sakai ..... Kagosima ..... Kii Peninsula.
Pugettia sagamiensis Gordon.. Tosa Bay ..... Sagami Bay.
P. quadridens pellucens Rathbun ..... Kii Peninsula .. Sagami Bay.
P. qu. intermedia Sakai ... Kii Peninsula .. Sagami Bay.
P. kagoshimensis Rathbun .. Kagosima ..... Sagami Bay?
P. minor Ortmann ..... Kii Peninsula .. Iwate-ken ..... Toyama Bay.
P. similis Rathbun ..... Ôse-zaki ..... Izu Peninsula ... Toyama Bay.
P. nipponensis Rathbun .... Tosa Bay ..... Siwoya-zaki.
P. elongatus Yokoya ..... Izu Peninsula.
Mimulus cristatus Balss ..... Sagami Bay.
Menaethiops okai Sakai ..... Izu Peninsula .. Kii Peninsula.
Choniognathus reini (Balss) ..... Sagami Bay .... Hukui-ken.
Rochinia debilis Rathbun ..... Sagami Bay.
Hyastenus kyusyuensis Yokoya ..... Tane Is. ..... Sagami Bay.
H. cornigerus Sakai ..... Kii Peninsula ... Izu Peninsula.
Chorilia longipes japonica (Miers) ..... Sagami Bay .... Sendai Bay.
Scyra compressipes Stimpson . Sagami Bay .... Hakodate ..... Syônai Prov.
S. tuberculata Yokoya ..... Kagosima.
Pisoides ortmanni (Balss)... Kii Peninsula ... Sendai Bay.
Maja japonica Rathbun ..... East China Sea.. Sagami Bay.
M. nipponensis Sakai ..... Tane Is. ..... Sagami Bay.
M. kominatoensis (Kubo) ... Danzyô Group .. Tokyo Bay.
Majella brevipes Ortmann ..... Sagami Bay.
Leptomithrax edwardsi de Haan ..... Nagasaki ..... Tokyo Bay ..... Syônai Prov.
L. bifidus Ortmann ..... Nagasaki ..... Tokyo Bay ..... Syônai Prov.

Schizophroida simodaensis SAKAI ..... Izu Peninsula.

S. manazuruana SAKAI ..... Izu Peninsula ... Sagami Bay.

Acanthophrys harmandi NOBILI ..... Kii Peninsula ... Sagami Bay.

A. brevispinosus (YOKOYA) .. Tane Is. ..... Kii Peninsula.

Tiarinia spinigera STIMPSON .. Nagasaki? ..... Kii Peninsula.

Leptopisa nipponensis SAKAI ..... Kii Peninsula.

Xenocarcinus nakazawdi SAKAI ..... Kii Peninsula .. Izu Isls.

X. monoceros SAKAI ..... Sagami Bay.

Heterocrypta transitans ORTMANN ..... Nagasaki ..... Sagami Bay.

Asterolambrus kusei SAKAI ..... Kii Peninsula.

Harrovia trilobata SAKAI .... Izu Peninsula ... Tokyo Bay.

BRACHYRHYNCHA

Jonas distincta (DE HAAN) ... Nagasaki ..... Sagami Bay.
J. d. formosensis (BALSS) .. Formosa.

Podocatactes hamifer ORTMANN ..... Nagasaki ..... Mutu Bay ..... Syônai Prov.

Portunus corrugatus strigilis STIMPSON ..... Nagasaki ..... Tokyo Bay.

Caphyra yo-okadai SAKAI .... Kii Peninsula ... Izu Peninsula.

Neptunus (Hellenus) nipponensis SAKAI ..... Kii Peninsula.

N. (Lupocycloporus) aburatsubo BALSS ..... Sagami Bay.

Thalamita kagosimensis SAKAI. Kagosima.

Kraussia quadriceps YOKOYA ..... Sagami Bay.

Trachycarcinus balssi RATHBUN ..... Nagasaki ..... Simushir Is. .... Toyama Bay.

T. sagamiensis RATHBUN ..... Sagami Bay.

Telmessus acutidens STIMPSON Tokyo Bay ..... Muroran ..... South Sakhalin. (Corea Strait)

Cancer japonicus ORTMANN .. Tosa Bay ..... Tokyo Bay ..... Syônai Prov.

C. tumifrons YOKOYA ..... Goto Isls. ..... Sagami Bay.

Halimede fragifer DE HAAN ... Nagasaki ..... Sagami Bay .... Isikawa-ken.

Atergatis subdentatus DE HAAN ..... Kii Peninsula ... Sagami Bay.

Eurypanopeus orientalis SAKAI ..... Sagami Bay.

Cycloxanthops quadrilobatus SAKAI ..... Kii Peninsula.

Carpoporus orientalis SAKAI ..... Sagami Bay.

Xantho truncata DE HAAN ... Nagasaki ..... Tokyo Bay ..... Toyama Bay.

Carpilodes sagamiensis SAKAI ..... Sagami Bay.

C. striolatus ODHNER ..... Bonin Islands ...

Neoliomera sakagutii SAKAI ..... Kii Peninsula.

Actaea bocki ODHNER ..... Formosa ..... Sagami Bay.

A. (Banareia) nobilii japonica ODHNER ..... Kii Peninsula ... Sagami Bay.

Etisus (*Etisodes*) *rhynchophorus* A. M. EDWARDS.....Izu Peninsula ...Tokyo Bay.

Actumnus forficigerus STIMPSON .....Amami Ôsima ..Sagami Bay.

A. intermedius BALSS .....Sagami Bay.

Pilumnus marginatus STIMPSON .....Loo Choo .....Sagami Bay.

P. dofleini BALSS .....Sagami Bay.

Heteropilumnus longipes (STIMPSON) .....Amami Ôsima ..Kii Peninsula.

Parapilumnus pearsei RATHBUN .....Kii Peninsula ..Sagami Bay ....Toyama Bay.

Heteropanope granulipes SAKAI .....Sagami Bay.

Calmania simodaensis SAKAI .....Izu Peninsula.

Ralumia balssi SAKAI .....Suruga Bay.

Carcinoplax surugensis RATHBUN .....Suruga Bay.

Heteroplax nagasakiensis SAKAI .....Nagasaki .....Osaka Bay.

H. nitida MIERS .....Corea Strait ....Sagami Bay.

Goneplax nipponensis YOKOYA.Nagasaki .....Izu Peninsula.

Ommatocarcinus fibriophthalmus YOKOYA .....Goto Isls.

Lophoplax takakurai SAKAI.....Sagami Bay.

L. sculpta STIMPSON .....Amami Ôsima.

Speocarcinus laevimarginatus YOKOYA .....Kagosima.

Ceratoplax sagamiensis SAKAI.....Sagami Bay.

Xenophthalmodes morsei RATHBUN .....Nagasaki .....Sagami Bay.

Hephthopelta aurita RUTHBUN.Tosa Bay .....Suruga Bay.

H. cribrolum RATHBUN .....Sagami Bay.

Megaesthesius yokoyai SAKAI..Bungo Strait.

Potamon (*Geothelphusa*) *formosensis* PARISI .....Formosa.

P. (*G.*) *globosa* PARISI .....Formosa.

P. (*G.*) *sakamotoana* RATHBUN .....Loo Choo.

P. (*G.*) *levicervix* RATHBUN .Loo Choo.

P. (*Potamon*) *rathbuni* DE MAN .....Formosa.

Pinnotheres boninensis STIMPSON .....Bonin Isls. .....Tokyo Bay.

P. pholadis DE HAAN .....Nagasaki .....Mutu Bay.

P. corbiculae SAKAI .....Kagosima.

P. bidentatus SAKAI .....Kii Peninsula.

Pinnaxodes mutuensis SAKAI.....Mutu Bay.

Ostracotheres subquadrata SAKAI .....Ise Bay.

Parapinnixa asiatica SAKAI .....Izu Peninsula.

P. yokoyai GLASSELL			Mutu Bay.
Pinnixa rathbuni SAKAI	Ise Bay		Mutu Bay.
P. balanoglossana SAKAI	Ise Bay		Tokyo Bay?
P. haematosticta SAKAI			Izu Peninsula.
Pseudopinnixa carinata ORTMANN			Tokyo Bay.
Asthenognathus inaequipes STIMPSON	Inland Sea		Mutu Bay.
Tritodynamia japonica ORTMANN	Ise Bay		Tokyo Bay.
Retropluma denticulata RATHBUN	Tinkai Bay (Corea)	Sagami Bay.	
Cymopolia longimana MIYAKE.	Loo Choo.		
C. kyusyuensis (YOKOYA)	Kosiki Islands.		
Gelasimus formosensis RATHBUN	Formosa.		
Hemiplax botel-tobagoe SAKAI.	Formosa.		
Paracleistostoma japonicum SAKAI	Nagasaki	Izu Peninsula.	
Ilyoplax pusillus (DE HAAN)	Nagasaki	Sagami Bay	Corea, west side.
I. formosensis RATHBUN	Formosa.		
I. tansuiensis SAKAI	Formosa.		
Ptychognathus ishii SAKAI	Formosa.		
Pt. takahasii SAKAI	Formosa.		
Acmaeopleura parvula STIMPSON	Amami Ôsima	Sagami Bay	Saisyûto.
Gaetice ungulatus SAKAI	Loo Choo.		
Sesarma (Parasesarma) vestita STIMPSON	Amami Ôsima		
Metaplax takahasii SAKAI	Formosa.		

The most extensively distributed species of this group are *Tymolus japonicus, Philyra syndactyla, Pinnotheres pholadis,* which range from Hakodate Bay or Mutu Bay to Kyûsyû. Though it is difficult to decide whether these species originated from southern forms or from northern forms, species allied to them are usually found in southern regions. Such genera as *Podocatactes, Scyra, Chorilia, Trachycarcinus, Pinnixa,* on the other hand, probably originated from northern forms, as the same or related genera are found on the north-west coast of America. The following species are peculiar to the Far East and have their kin in northern forms—*Podocatactes hamifer, Scyra compressipes, Chorilia longipes japonicus, Trachycarcinus balssi, Trachycarcinus sagamiensis, Pinnixa rathbuni, Pinnixa haematosticta,* etc.

Among the entirely endemic Japanese species, no less than 90 are found in Sagami Bay. Tokyo Bay, Izu Peninsula, Kii Peninsula, Tosa

Bay, Kagosima, Nagasaki are also represented by a vast number of species. In other localities the number are fewer, probably owing to the insufficiency of the investigation so far performed, as also to the unfavorable habitat conditions. The species found in the localities north of Tokyo Bay are only 20 in number, while the localities on the Japan Sea side have about 19, of which about 10 species are common to both coasts. It may therefore be concluded that in the faunal aspect these coasts closely resembles with each other.

VI. Distribution in Japanese waters of the species found in the northern cold districts of the Pacific Ocean

The northernmost regions of the Pacific Ocean, bounded by northern California, west coast of Canada, Alaska, Behring Sea, Kamchatka, Kurile Islands, Okhotsk Sea, comprise some peculiar species, although they are very few in number. Such genera as *Telmessus, Erimacrus, Chionoecetes, Hyas, Chorilia, Cancer, Pisoides, Pugettia, Pinnixa, Parapinnixa, Pinnaxodes,* etc. are peculiar to these regions; but the species common to northern Asia and north-west coast of America are relatively fewer; such species are:

Telmessus cheiragonus (TILESIUS)
Erimacrus isenbeckii (BRANDT)
Cancer amphioetus RATHBUN
Oregonia gracilis DANA
} rather deep water inhabitants.

Pachygrapsus crassipes RANDALL .... the unique rock hunter in these regions.
Hyas coarctatus alutaceus BRANDT.... circumpolar species.

On the other hand, the species restricted to the northern cold regions of the Far East are:

Hyas coarctatus ursinus RATHBUN
Chionoecetes opilio elongatus RATHBUN
Telmessus acutidens STIMPSON
Chorilia longipes japonicus (MIERS)
Pisoides bidentatus (A. M. EDWARDS)
} rather deep water inhabitants.

On the Pacific side, *Telmessus cheiragonus* does not range to south of Hakodate, while *Telmessus acutidens* ranges southward to Tokyo Bay; *Erimacrus isenbeckii* ranges to north of Sendai Bay, *Oregonia gracilis* to north of Inuboe-zaki; *Chionoecetes opilio elongatus, Chorilia longipes japonicus,* and *Pisoides bidentatus* range southward to Sagami Bay, and *Cancer amphioetus* to Suruga Bay, but there is no record of distribution of *Hyas* on the Pacific side. *Pachygrapsus crassipes,* the

unique rock hunter of this group, ranges over almost the entire coast of Japan, Pacific and Japan Sea sides, as also to the coast of Corea.

On the Japan Sea side, *Telmessus cheiragonus* is restricted to the waters north of Hokkaidô and the coasts of Siberia, while, *Cancer amphioetus, Oregonia gracilis, Hyas coarctatus alutaceus, Hyas coarctatus ursinus, Pachygrapsus crassipes* range southward to the Yellow Sea or Peichihli Bay or even to Amoy as *Hyas coarctatus ursinus; Erimacrus isenbeckii, Chionoecetes opilio elongatus, Telmessus acutidens* range toward Corea Strait but not southward from this region.

Pinnixa, Parapinnixa, Pinnaxodes occur mostly on the coasts of America as mentioned above, while the Japanese *Pinnixa rathbuni* is closely related to the American *Pinnixa occidentalis* and the Japanese *Parapinnixa yokoyai* is a near kin of the American *Parapinnixa affinis.*

Finally, I quite agree with the previous authors in admitting no direct influence of the cold current to the fauna of the warmer localities on the Pacific side of Japan, since the species of the northern origin are rarely found beyond Sagami Bay or Tokyo Bay. *Cancer amphioetus* and *Pachygrapsus crassipes* form the exception to this rule. the former being found in Suruga Bay and the latter on the entire coast of the Japanese mainland. On the Japan Sea side, the influence of the cold current reaches farther southward than on the other side, many species of the northern origin being found on the entire coast along the Japan Sea, Yellow Sea, Peichihli Bay and even toward Shanghai or Amoy. The continuity of the fauna between Peichihli Bay and Amoy or Shanghai may be accounted for on some cold current existing along the coast of China.

VII. Cosmopolite species found in Japanese waters

The cosmopolite species found in the waters around Japan are very few:

Ovalipes punctatus (DE HAAN) .....entire Japan.
Domoecia hispida EUDOUX & SOULEYET .....Loo Choo.
Pilumnoplax americana RATHBUN .....Pacific side.
Planes minutus (LINNAEUS) .....Pacific side.

Ovalipes punctatus, Planes minutus are both pelagic in habit; the former is a swimming crab, occurring around the entire region from Hokkaidô to Formosa, and distributed to America, Atlantic Ocean, and South Africa; the latter is also pelagic, but usually found attached

to floating timbers, sea-weeds, jellyfish, or to sea-turtles, and have been recorded from the entire warmer region in the Pacific, Indian, and the Atlantic Oceans, its occurrence being known in the south of Tokyo Bay to Formosa. *Domoecia hispida* is an inhabitant on the coral reef, and known from Florida, Brazil, and the tropical Indo-Pacific, the record of its occurrence in Japan being from Loo Choo. *Pilumnoplax americana* is an inhabitant of the continental shelf, ranging from Florida to India and Japan (from Sagami Bay to Tosa Bay), but without any continuity of distribution between these localities.

Homola (*Parhomola*) *japonica* Parisi in the Japanese and Hawaiian waters closely resembles *Homola cuvieri* Risso from the Mediterranean; *Neptunus* (*Hellenus*) *nipponensis* Sakai from Kii Peninsula also stands very near to the Atlantic rare species, *Neptunus vocans* A. M. Edwards; both are deep sea forms and are characterized in having the stridulating apparatus. The genus *Carpoporus* comprises only two species, one, *C. papulosus* Stimpson from Florida and the other, *C. orientalis* (rather shallow water inhabitant) from Sagami Bay; *Leptopisa* also comprises only two species, one, *L. setirostris* (Stimpson) from Florida Keys to Northern Brazil, and the other, *L. nipponensis* Sakai from Kii Peninsula. Although it is rather common to find a close agreement in deep-sea animals occurring even in extremely remote localities, such cases are seldom among shallow-water inhabitants. Thus the cases found in *Domoecia* and *Carpoporus*, mentioned above, remain to be explained only by future thorough studies of their distribution.

VIII. Conclusion

In my recent monograph of the Japanese crabs, about 675 species referable to 253 genera and 25 families are enumerated to be inhabiting the Japanese waters. These are composed of four elements as viewed from their distributional phases.

(1) The forms endemic to Japan as well as to China or Manchoukuo (about 240 species), (2) those propagated from the tropical Indian, Malaysian, and Pacific Ocean (about 420 species), (3) those propagated from the northernmost regions of the Pacific Ocean (about 11 species), and (4) the cosmopolite species (about 4 species). Those belonging to (1) may be divided into three subgroups: (a) the genuine Indo-Pacific, (b) Indian, and (c) the tropical Pacific forms. The group belonging to (b) may be also divided into two subgroups: (i)

those propagated from the extensive Indian Ocean and (ii) those distributed in the northern coasts of the Indian Ocean, Malay Peninsula, and the Far East.

The groups originated in the southern tropical localities show their own aspects with regard to the distribution of each species in the Japanese waters, but the decrease of the number of the species in various localities, from Formosa to Tokyo Bay, is largely uniform and gradual, the only remarkable gap being recognized at the border region between the Kurosiwo and Oyasiwo, viz. north of Tokyo Bay or off the coast of Bosyû. These tropical species are gradually mixed with the Japanese endemic species in various localities south of Tokyo Bay, and only a small number extend beyond the said gap toward the northern localities, to be mixed with those propagated from the cold waters.

As compared with those genuine Indo-Pacific species, the Indian species and the species endemic to the Far East range more northward beyond the gap, going up to Usu Bay or Akkesi in Hokkaidô, and even to Sakhalin. The tropical Pacific species likewise extend northward as much as the Indian or the Far Eastern species; many species belonging to that group are common to Japan and Hawaii, or to Japan and Australia or New Caledonia.

The species originated in the boreal regions may range to Sagami Bay, but never beyond this locality, except a few such as *Cancer amphioetus* (Suruga Bay) and *Pachygrapsus crassipes* (entire Japan). On the Japan Sea side, however, many boreal species extend farther southward to Corea Strait, Yellow Sea, Peichihli Bay or even toward Amoy.

Few southern tropic forms, as well as the Far Eastern forms, go into the Japan Sea, compared with the Pacific side. Their range on that side, however, extends farther northward than on the Pacific side, most of the species reaching Syônai Province in Yamagata-ken. Thus, the southern and northern forms as well as the Far Eastern forms, are gradually mixed on the Japan Sea side, from Corea Strait toward Syônai Province, no apparent gap in number of species exists.

The crab fauna of Loo Choo, Bonin Islands, Northern Daitô-zima, and Formosa is quite tropical, the species inhabiting these regions are almost the same as those found in the tropical Indian, Malaysian, and Central Pacific regions, comprising a few local species but none of boreal origin.

With regard to the fauna of the east coast of Corea, we are at

present quite ignorant, as the investigation has not yet been performed, while on the Yellow Sea side, the littoral fauna seems to resemble that of Nagasaki or Saisyûto, where the inhabiting species resamble those of the Pacific side of Japan, while the freshwater fauna is very close to that of North China or Manchoukuo. The fauna of the Yellow Sea is mixed with the southern and northern forms, but comprises such peculiar species as *Orithyia sinica*. The fauna of Peichihli Bay (China) is largely similar to that of Aomori Bay or Hakodate, the peculiar *Pinnixa tumida* being recorded from both of these localities.

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I. Dromiacea—Sci. Rep., Tokyo Bunrika Daigaku, sec. B, vol. 3, Suppl. No. 1, 1936.

II. Oxystomata—Sci. Rep., Tokyo Bunrika Daigaku, sec. B, vol. 3, Suppl. No. 2, 1937.

III. Brachygnatha, Oxydhyncha—issued from Yôkendo, Tokyo, 1938.

IV. Brachygnatha, Brachyrhyncha—issued from Yôkendo, Tokyo, 1939.

Studies on Marine Deposits

II. On the Stratified Settling of Fine Mud in Water*

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(With 8 Text-figures and 5 Tables)

I. Introduction

In the previous paper,[1] one of the writers made a study on the action of sea-salt upon the sedimentation of fine mud, and observed that, when the initial turbidity and salinity of water were small, a very marked stratification as shown in Fig. 1 appeared in the sedimentation of fine mud. Interested by this peculiarity, the present writers commenced another study on this phenomenon, the result of which is now reported here. They believe that in a turbid sea or lake similar phenomenon of large scale may sometimes occur, and if so, the phenomenon will be very important not only from the physico-chemical standpoint but also from the oceanographical and even fishery viewpoint.

In usual settling of turbid water, subsidence takes place in such a way that there is at all times a continuous increase in opacity of the mixture from the top toward the bottom, whereas with the stratified subsidence, the mixture divides itself into sections, each of which is more or less uniform in opacity, but at the transition surface from the upper to the lower section, the opacity increases by a sudden jump. Careful observation shows that the opacity in one and the same section also varies according to the height, being greater in the upper and smaller in the lower part of the section, as schematically shown in

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* An outline of this paper was read before the meeting of the National Committee of Japan on Pacific Oceanography on Dec. 21, 1929. But at that time, the mechanism of formation of the stratified settling was not so clear. Hence we continued several experiments chiefly on this mechanism, and the newly obtained results are contained in the present paper.

1) These Records, **9**, 1 (1937).

Fig. 1 a.

Fig. 1 a.

The stratified settling of fine mud in water or some other liquid has already been studied by many investigators. W. H. BREWER[1] and C. BARUS[2] have observed stratified subsidence, but arrived at no conclusion as to the cause of the stratification. After a minute study of the conditions under which stratified settling developed, P. EHRENBERG, E. HAHN and O. NOLTE[3] reconcluded the EHRENBERG and SCHULTZE's[4] consideration that the cause of the formation of stratified strata might be due to the difference of the dimension and the weight of the suspensoid in liquid. E. UNGERER[5] also insisted on the same conclusion.

A further research was conducted by M. MASON and C. E. MENDENHALL.[6] Rectangular tubes were made, two opposite sides of which were in contact with water baths of different constant temperatures, and radial gradients were produced by an arrangement of three concentric tubes, the central one carrying a current of warm water, the outer a cool bath with various specially controlled temperature gradient. Observing with these apparatus, they concluded that stratification occurs only when there is a lateral temperature gradient across the liquid which causes weak convection currents.

On the other hand, Einstein[7] developed a statistical theory of Brownian movement which gave the equilibrium distribution of one size of particles suspended in a liquid, and Perrin[8] verified the Einstein theory of stable distribution by actual counting and measurement. But P. G. NUTTING[9] proposed a theory which is much simpler and more general than that of Einstein's, which gave Perrin's law of distribution as a special case and even covered stratified settling quite adequately as he said. At any rate Nutting attributed the cause of stratified settling to the upward pressure gradient due to Brownian motion of particles.

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1) Memoirs Nat. Acad. Sci., Washington, **2** (1884).
2) Koll. Zeit., **9**, 14 (1911).
3) Ditto, **21**, 1 (1917).
4) Ditto, **15**, 183 (1914).
5) Kolloidchem. Beihefte, **14**, 63 (1921–22).
6) Proc. Nat. Acad. Sci., **9**, 199, 202 (1923).
7) Ann. Phy., **17**, 549 (1905).
8) Comptes rend, **146**, 968 (1908).
9) Jour. Washington Acad. Sci., **19**, 402 (1929).

II. The Production of Stratified Settling

Stratified suspensions are readily prepared with almost any kind of fine particles of mud shaken up in a glass tube with water or any liquid. We used grayish clay for the Kiyomidu-ware, Kyoto. It was first dried and further pulverized in a mortar. Next we sifted only the finest particles of mud through a sieve of 0.03 mm meshes. About 5 grm of the fine mud thus obtained was dissolved in a definite quantity of water, and left for one or two days in order to saturate the dried mud with water uniformly.

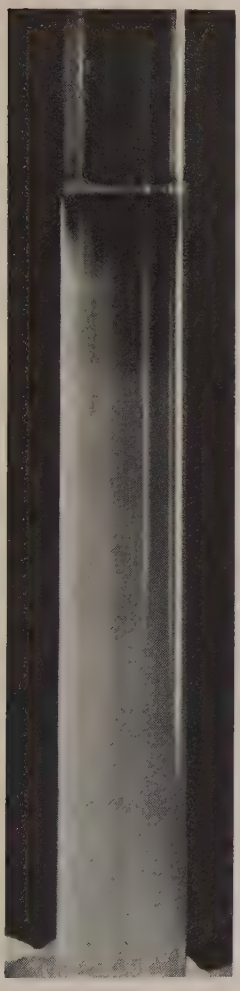


Fig. 1 b.

The prepared mud-water was mixed with pure water or aqueous salt solution of a definite concentration, so as to make both the quantity of mud and the concentration of salt as we desired. If the above mentioned mud water was settled in a glass tube (diameter 2 cm, length 20 cm), many discontinuous layers of fine mud particles occured in two or three days, rarely in a week as shown in Fig. 1 b. The same stratified settling of fine mud particle appears even in a mixture of water and glycerin as in the case of water.

As the suspensoids, in general, are easily coagulated by addition of a fairly large quantity of salt, the stratified settling of fine sediment can not be observed in this case. With regard to the action of sea-salts upon the sedimentation of fine mud, one of the writers and T. TAKEGAMI[1] have made studies. In our study of the stratified settling of fine mud sediments we find that it appears in aqueous salt solution of definite concentration or pure mud water and more easily appears in diluted mud water than in concentrated liquid.

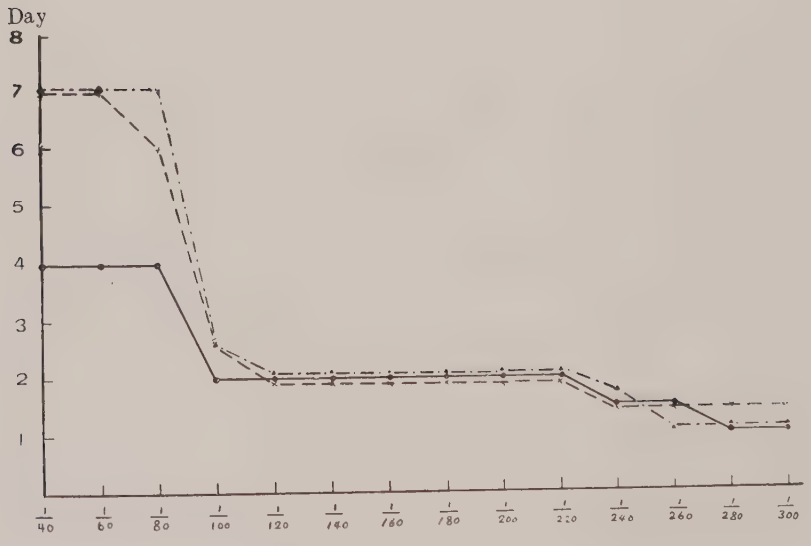
To get a general idea of the relation between the concentration of fine mud water of no salinity but of various turbidities, and the time when the stratified settling of fine sediment

1) p. 65.

begins to develop; the results of three series of experiments are plotted in Fig. 2 by taking the lapse of time as ordinates and the concentration of mud water as abscissae. The signs •, ▲ and × denote the series of the experiment of the time when the stratified settling of fine mud first developed.

As is evident from the curves thus plotted, the stratified settlings of fine mud appear within two days for diluted mud water, but in 4–7 days for concentrated mud water.

Fig. 2.



Turbidity in ca. 1 gr. mud per c.c.

Table I shows the relation between the concentration of NaCl of mud water and the lapse of time when the stratified settling of fine sediments developed in the case when about 1 gr of fine mud was dissolved in 80 cc water. From the following Table it is clear that in the concentration of 1/40~1/100 normal sea water one or two strata of fine mud appear, while in the concentration of 1/600~1/900 normal sea water several strata appear, the turbidity being ca. 1 gr fine mud in 80 cc of water. This shows that the stratified settling can occur more easily, if the salinity is smaller.

Table I.

Normality of NaCl	Time when strata developed	Numbers of strata	Remarks
1		0	
$\frac{1}{2}$		0	
$\frac{1}{5}$		0	
$\frac{1}{10}$		0	
$\frac{1}{20}$		0	
$\frac{1}{30}$	5 hr	1	The developed strata are all very obscure and the settling is very fast, so that the strata disappeared in a short time
$\frac{1}{40}$	5	1	
$\frac{1}{50}$	6	2	
$\frac{1}{60}$	5	2	
$\frac{1}{70}$			
$\frac{1}{80}$	7	2	
$\frac{1}{90}$	7	1	
$\frac{1}{100}$	1 d	2	1 cm & 2 cm from surface
	1 d 5 hr	2	1.8 cm & 6.5 cm from surface
	2 d	0	
$\frac{1}{120}$	1 d	2	1 cm & 2 cm from surface
	1 d 5 hr	1	
	2 d	0	
$\frac{1}{140}$	1 d	2	1 cm & 2 cm from surface
	1 d 5 hr	4	2 cm, 3 cm, 7 cm & 8 cm from surface
	2 d	2	4 cm & 7 cm from surface
	3 d	0	
$\frac{1}{160}$	1 d	2	1 cm & 2 cm from surface
	2 d	1	2.5 cm from surface
	3 d	0	
$\frac{1}{180}$	1 d	2	1 cm & 2 cm from surface
	1 d 5 hr	4	
	2 d	2	1.5 cm & 5 cm from surface
	3 d	0	
$\frac{1}{300}$	5 d	1	
	6 d	2	
	7 d	1	
	8 d	1	
	10 d	0	

Normality of NaCl	Time when strata developed	Numbers of strata	Remark
$\frac{1}{400}$	5 d	2	
	6 d	3	
	7 d	2	
	8 d	1	
	10 d	0	
$\frac{1}{500}$	5 d	3	
	6 d	3	
	7 d	3	
	8 d	2	
	10 d	1	
$\frac{1}{600}$	5 d	4	
	6 d	3	
	7 d	2	
	8 d	2	
	10 d	1	
$\frac{1}{700}$	5 d	6	
	6 d	5	
	7 d	4	
	8 d	3	
	10 d	2	
$\frac{1}{800}$	5 d	7	
	6 d	6	
	7 d	4	
	8 d	4	
	10 d	3	
$\frac{1}{900}$	5 d	5	
	6 d	6	
	7 d	5	
	8 d	3	
	10 d	3	
$\frac{1}{1000}$	5 d	5	
	6 d	5	
	7 d	5	
	8 d	5	
	10 d	4	
0 (pure water)	8 d	2	

III. Settling Velocity of Stratified Layers

Table II and III show the settling velocity of strata which developed in a tube, as uniform as possible. The former indicates the settling velocity of mud strata appearing in pure mud water, the turbidity ca. 1 gr mud per 80 cc, and the latter in the case of mixed water with glycerin in ratio of 4 to 1, the turbidity ca. 1 gr mud per 40 cc.

As seen from Table II and III, the settling velocity of the lower strata is greater than that of the upper successive ones. This fact gives a good suggestion as to the reason why the upper part of any one stratum is dense while the lower part of it is rare as seen in Fig. 1 a. In other words, by the difference in velocities of any two successive strata, the distance between these two becomes greater and the uppermost part of a stratum bcomes sharply denser but the lower part of it more rare and obscure. Nuttings' upward pressure due to Brownian motion of particles can not explain this peculiarity.

Owing to the influence of the room temperature, the measured settling velocities of strata differ on different days. It is clear from the well known Stokes' law that the falling velocity of substance in liquid depends on the viscosity and the temperature of the liquid.

Table II. Settling velocity of mud strata appearing in pure mud water, the turbidity ca. 1 gr mud per 80 cc

Date	Number of strata (from upper)			
Jan. 28 (1928) 10 hr Beginning	I	II	III	IV
	mm/hr	mm/hr	mm/hr	mm/hr
Feb. 1 $15\frac{1}{6}$	0.11	0.43	0.71	1.03
2 9.5	0.34	0.59	1.06	1.89
2 $15\frac{1}{3}$	0.14	0.39	0.73	0.96
3 $12\frac{3}{4}$	0.31	0.53	0.66	0.93
4 $11\frac{1}{4}$	0.32	0.57	0.93	1.15
5 15	0.26	0.62	0.89	0.98
6 $13\frac{1}{2}$	0.10	0.40	0.60	0.70
7 $9\frac{1}{2}$				

Table III. Settling velocity of mud strata appearing in mixed water with glycerin the rate of 4 to 1, the turbidity ca. 1 gr mud per 40 c.c.

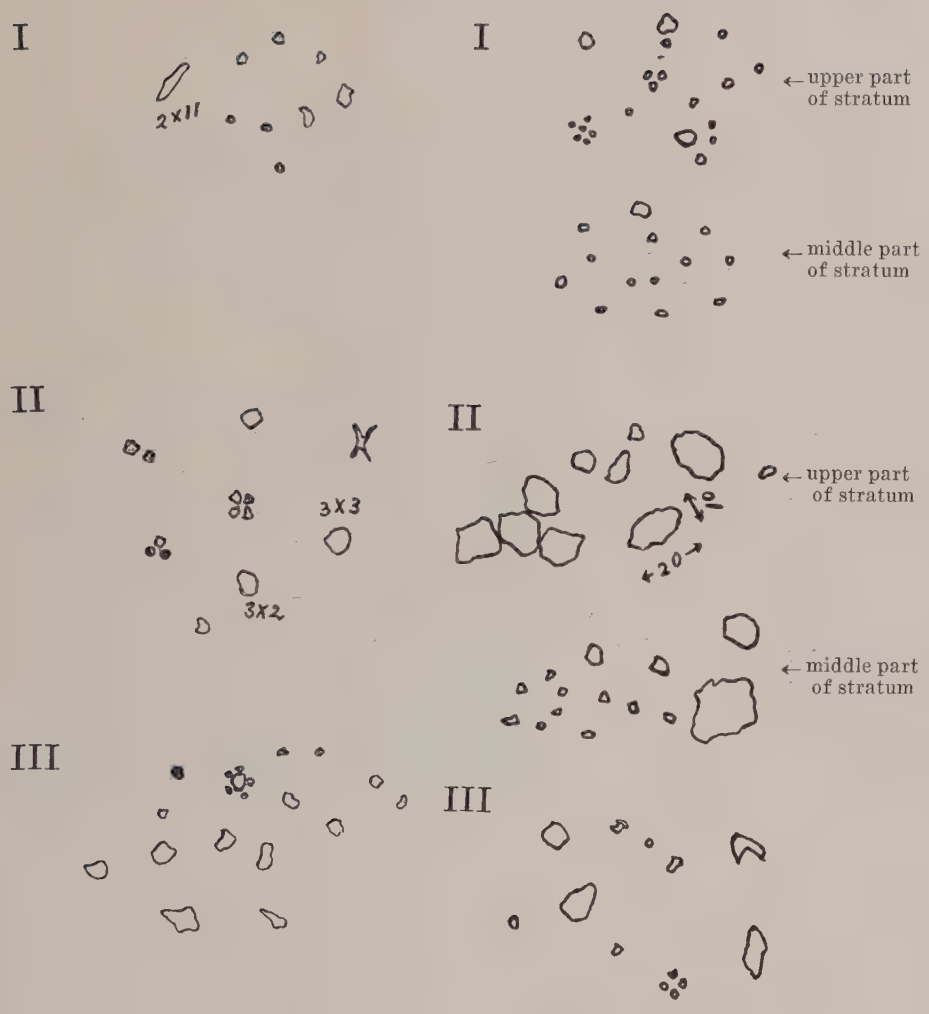
Date	Number of strata (from upper)			
Jan. 26 (1928) 10 hr Beginning	I	II	III	IV
	mm/hr	mm/hr	mm/hr	mm/hr
31 13	0.10	0.18	0.27	0.42
1 $14\frac{3}{4}$	0.12	0.15	0.23	0.30
2 $13\frac{1}{2}$	0.09	0.16	0.33	0.47
3 13	0.09	0.14	0.25	0.32
4 14	0.01	0.23	0.32	0.41
5 $14\frac{1}{2}$	0.14	0.21	0.32	—
6 $14\frac{1}{2}$	—	0.20	0.34	—
7 15	0.13	0.22	0.26	—
8 14	0.12	0.21	0.41	—
9 14				

IV. Microscopic Investigation

The form and size of the mud particles taken by a pipette from the upper and middle parts of the various strata developed in a glass tube, were investigated by means of a polarization microscope. Some of the results are shown in Fig. 3. The size and form of the mud particles are very irregular and the sectional area varies from 1.3×1.3 to $1.3\times2.6\mu^2$. From the above microscopic investigation we may say that the dimension of the particles gradually increases from the upper to the lower, but sometimes we find very large irregular particles, and these are minerals, ascertained by a polarization microscope.

Thus we are obliged to consider that the mean density of mud water is greater in the lower stratum than in the upper.

Fig. 3.



V. X-ray Investigation

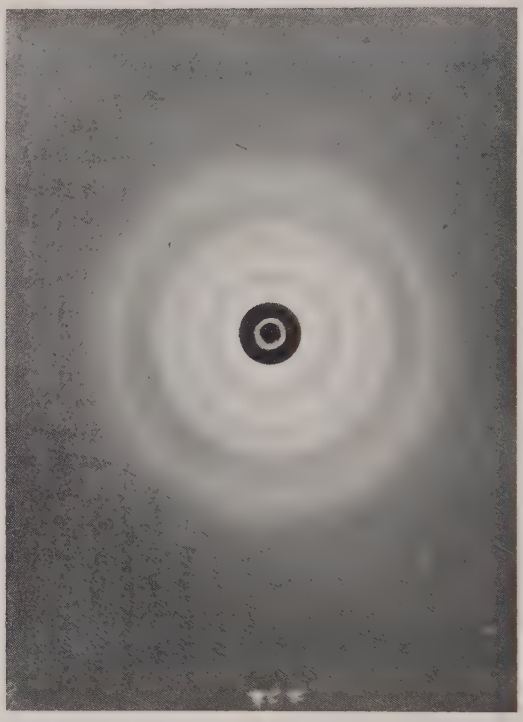
The sample of mud which had developed stratification in a glass tube was dried and then studied by taking the *X*-ray diffraction pattern to examine the order of pulverzation. The *X*-ray diffraction photograph is shown in Fig. 4, and the lattice constants of the mud calculated from the figure are also tabulated in Table IV. The small Laue's spots in Fig. 4 are due to the large irregular crystals of mud already noted in the microscopic investigation and the many interference circles

are due to the small particles of the mud. They suggest that the mud is composed of small crystals.

Table IV.

No. of Interference circle	θ (glancing angle)	d (lattice constant)	Remark
		Å.U.	
1	5° 54′	7.49	
2	9° 47′	4.53	
3	12° 53′	3.45	small Laue's spots
4	16° 52′	2.65	
5	18° 54′	2.37	
6	22° 59′	2.00	
7	24° 8′	1.88	
8	26° 58′	1.70	

Fig. 4.

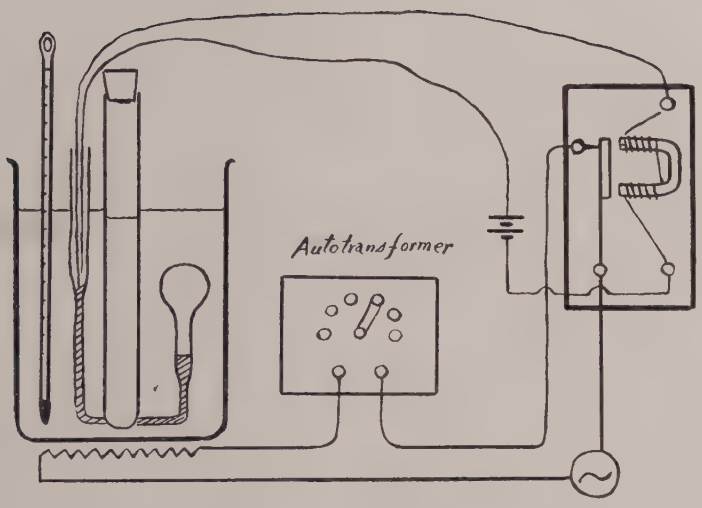


VI. Mechanism of Stratification

A test glass tube (diameter 2 cm, length 20 cm) containing the mud water was put into a large water bath. A U-shaped glass tube, as shown in Fig. 5, having at one end a closed spherical bulb filled with air and the other part filled with mercury, was also put into a large water bath to keep it in constant temperature. The arrangement of the heating system and the other series were made as in Fig. 5. Unfortunately, the constant-temperature bath thus constructed ended in a failure, but it was controlled within 5°C.

The experimental results using these apparatus are tabulated in Table V. The successive transformations of fine mud particles developing the strata in a tube are shown in Fig. 6 schematically. Thus we found the artificial stratified-settling of fine mud particles in a very

Fig. 5.

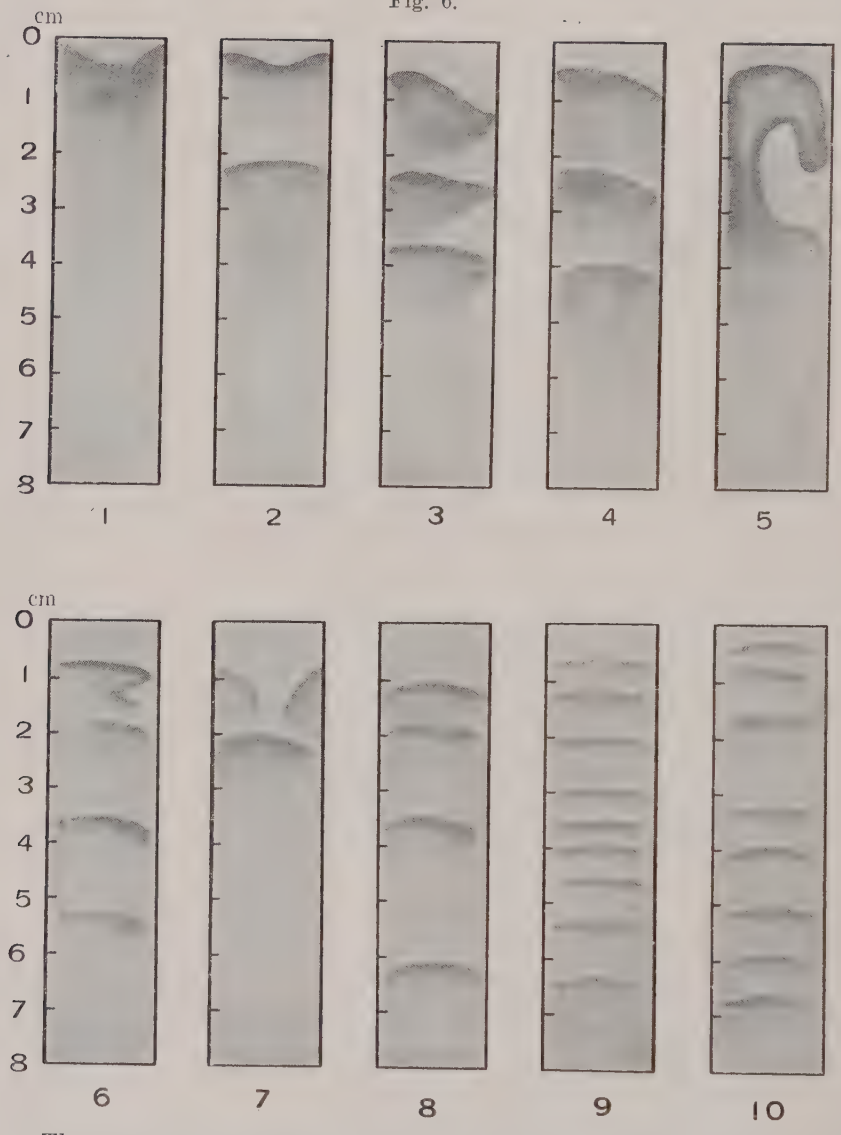


short time. It is clear that the stratified settling of fine mud developes either by heating or cooling.

Table V. Artificial stratified settling being made on Oct. 7, 1937

Time		Temperature of bath	Remark
h	m	°C	
8	50	20.0	The experiment was begun
	55	24.3	no change
9	0	28.0	„
	5	30.5	„
	10	32.6	Fig. 6, 1
	11	33.6	The electric current of heating system was opened
	15	33.0	Fig. 6, 2
	20	32.1	Fig. 6, 3
	25	31.3	Fig. 6, 4
	35	30.0	no remarkable change
	40	29.3	Fig. 6, 5
	50	28.2	Fig. 6, 6
10	0	27.0	no remarkable change
	1	27.0	The electric current of heating system was closed
	3	28.8	no remarkable change
	5	29.7	Fig. 6, 7
	10	32.2	Fig. 6, 8
	12	32.8	The electric current of heating sytsem was opened
	17	28.0	Fig. 6, 9
13	30	23.7	Fig. 6, 10

Fig. 6.



Thus we reached the conclusion that the principal cause of the stratified settling is a system of weak convectional circulation due to a minute temperature-difference in the mud water along the tube-wall which depends on the difference of thickness of wall.

In order to ascertain the above consideration that the temperature difference in the muddy water is caused by the difference of the heat

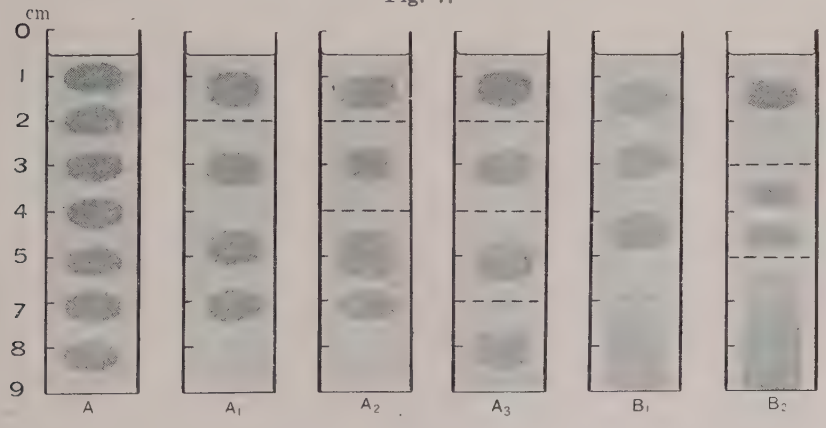
conduction due to the difference in thickness of the wall of the tube, the following experiments were carried out:

A quantity of mud water of the same turbidity was put in two test-tubes, (diameter 2 cm, length 20 cm) of uniform size, and along one side of each tube a scale was attached. The positions of the development of the stratified settling were examined with the same condition in the above apparatus.

It was found that the positions of these developments were due to the local difference in thickness of the tube, even if we choosed the tubes as uniform as possible; the one (A-tube) had seven strata, 1 cm apart from one another but the other (B-tube) four strata as indicated in Fig. 7. The same experimental data have been obtained by natural stratified settling.

Now a copper wire i.e. a good conductor of heat (the diameter being about 0.5 mm) was put around the outside of the A-tube and the same experiment was made in the above arrangement. We confirmed that the stratified settling was observed just above the position of the copper wire. Next another copper wire was fixed 2 cm apart from each other. The third, one more wire was placed. The experiments were carried out in a similar condition in the water bath, and the stratified settling of mud particles was observed just above the copper wires which were fixed just outside of the tube. The same results were obtained in the case of the B-tube also. The schematical figures are shown in Fig. 7.

Fig. 7.



From the above series of experiments we reached the conclusion

that the cause of development of the stratified settling in a tube is dependent on the minute difference of conductivity of heat which is due to the thickness of the wall of the tube. This difference causes weak convection currents in the tube.

Thus the distribution of size of mud particles in each stratum will be inversed by convection current, greater in the upper and smaller in the lower. This coincides well with the results of the microscopic investigation that the distribution of the mud particles in a stratum is not uniform, but the dimension of particles in the uppermost part is greater than that of the middle part. But when we compare the dimensions in the successive strata, it is observed that the mean dimension of the particle gradually and minutely increases from the top stratum toward the bottom stratum as has already been noted.

The difference of grain size or weight of course may be a cause of stratified settling if the suspension is a mixture of grains differing discontinuously in size or weight, especially if it is prepared by mixing entirely different sorts of grains as in the case of EHRENBERG and his coworkers.[1] But the stratified settling occurs even though there is no discontinuity in size or weight of grains, and scientific interests are greater for such a case to which our experiments belong. The phenomenon can not be explained by NUTTING's theory,[2] because his theory requires that the turbidity in a stratum must increase downwards, contrary to the fact, and because the stratification occurs even though the Brownian motion is stopped by addition of a small amount of gelatin solution as shown by UNGERER.[3] The convectional circulation theory of MENDENHALL and MASON[4] is right, but we can not accept their insistence that a lateral gradient of temperature is the necessary condition, for as shown by our experiments, the stratification will be generated even if the surrounding temperature is uniform, provided that the temperature is rising or falling slowly.

The above discussions concern with the settling of small scale as in a test-tube, but in lakes or seas also similar phenomena are often observed actually. In the latter case also, the direct cause will be a system of convectional circulations, and the circulations may be of various origin, for instances, the difference in temperature or

1) See p. 65.
2) See p. 66.
3) See p. 66.
4) See p. 66.

salinity of water or the wind action, etc. SANDSTRÖM's[1] experiment on the coastal circulations produced by wind will be a best explanation. By such circulations, even grains coarser than silt may be possible to form several layers.

VII. Summary

The main results obtained from the present experiments are summarized below:

(1) The mechanism of formation of the stratified settling of fine mud in water is discussed, and a system of weak convectional circulations is taken as the primary cause of the stratified subsidence.

(2) For the test-tube experiments, the convectional circulations are generated by a temperature gradient around the tube. Even if a tube as uniform as possible is taken, there is a minute local difference in thickness of the tube-wall, and therefore a difference in the conduction of heat even from the surrounding of uniform temperature may occur and thus the temperature gradient in the water along the tube-wall will be generated. The dimension of the convectional circulation and consequently of the stratified section of turbid water depends on the size of the test-tube.

(3) In some turbid sea or lake also, we may expect a similar stratified settling of large scale. But in this case, the causal convectional circulations may be due to various other causes as well as temperature difference.

(4) An artificial method of quick formation of stratified settling in a tube is devised.

In conclusion the writers' sincere thanks are due to the Nippon Gakuzyutu-Sinkokwai for the grant given to one of the writers (T. N.) with which this research was accomplished.

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1) SANDSTRÖM, Ann. d. Hydrogr. 1908, p. 7; Wedderburn, Proc. Soc. Edinb., 28, 13 (1908).

昭和十五年二月五日　印刷
昭和十五年二月十日　發行

帝國學士院會館內
學術研究會議

印刷者　東京市神田區美土代町十六番地
島連太郎

印刷所　東京市神田區美土代町十六番地
三秀舍